A BEHAVIORAL ECONOMIC ANALYSIS OF THE EFFECTS OF UNIT PRICE SEQUENCE ON DEMAND FOR MONEY IN HUMANS

Jack Keith Williams, Jr., B.S.

Thesis Prepared for the Degree of

MASTER OF SCIENCE

UNIVERSITY OF NORTH TEXAS

May 2002

APPROVED:

Cloyd Hyten, Major Professor
Richard Smith, Committee Member
Manish Vaidya, Committee Member
David W. Hartman, Dean of the School of Community Service
C. Neal Tate, Dean of the Robert B. Toulouse School of Graduate Studies

Williams, Jack Keith, *A behavioral economic analysis of the effects of unit price sequence on demand for money in humans*. Master of Science (Behavior Analysis), May 2002, 66 pp., 5 tables, 16 figures, references, 33 titles.

Three groups of participants were exposed to different unit price sequences. Unit prices for all groups ranged from unit price 1 to 21. Analyses of demand curves, response rates, session duration, and elasticity coefficients suggest that the sequence of exposure to unit prices can affect the elasticity of demand. In addition, the size of unit price contrast, direction of unit price change, and proximity to experimental milestones also may affect the consumption of monetary reinforcers.

ACKNOWLEDGMENTS

I would like to thank Dr. Cloyd Hyten for his time, effort, and advice given over the past several months during the course of this research. As my major professor his input has been invaluable.

TABLE OF CONTENTS

Page

LIST OF TABLES

Table

LIST OF ILLUSTRATIONS

Figure

CHAPTER 1

INTRODUCTION

Through the experimental analysis of behavior, basic researchers have sought to empirically determine the role of environmental factors in controlling behavior. One of the more recent developments of this research is the hybrid field of behavioral economics. Behavioral economics has been defined by Hursh (1980; 1984) as the integration of microeconomics' classification, terminology, research methods and analysis within the theoretical and experimental framework of behavior analysis. This field has expanded the conceptual tools for the prediction and control of both human and non-human operant behavior in various contexts (Bickel, Green, & Vuchinich, 1995). Behavioral economic theories and concepts have generated a great deal of research, but the field has only begun to capitalize on the potential benefits of such a unique way of viewing the factors that control behavior (see Bickel & Vuchinich, 2000).

Behavioral economic theory views operant behavior as the behavior of consumers in the economic sense. With this conceptualization of behavior, one can study the relationships between the levels of consumption of a commodity and specific commodity prices. This is called the analysis of demand (in contrast to the study of supply side economics). In basic behavioral economic research investigating demand, an artificial economic system is devised for experimental study. Fulfillment of response requirements, allocation of behavior between response alternatives, and consumption of

experimentally controlled reinforcing commodities can be studied within that system, utilizing theory, concepts and analytical tools regarding demand. Research has shown that response requirements, reinforcer magnitude, and the availability and nature of other reinforcing commodities influence demand in orderly ways (Green & Freed, 1993; Bickel, DeGrandpre, Higgins, & Hughes, 1990).

One way in which behavioral economic studies differ from traditional behavior analytic investigations of response-reinforcer contingencies is in the emphasis on consumption of a reinforcer as a major dependent variable rather than on response rate. In the economic view, response rate is seen as the means by which an organism produces access to and consumption of a reinforcing commodity; the relation of primary interest is between response allocation and consumption of the commodity of interest.

Unit price (UP) is a principal independent variable in the behavioral economic study of demand. UP quantifies the interaction between reinforcer magnitude and the response requirement to produce that reinforcer in terms of a cost-benefit ratio. This ratio represents a combination of several independent variables. Thus, UP is a flexible independent variable, in which any of the component figures can be altered to suit the purposes of the experimental conditions (DeGrandpre, Bickel, Hughes, Layng, & Badger, 1993). Hursh's (1991) definition of UP in terms of the cost-benefit ratio is shown in the following equation:

$$\text{Unit Price} = \frac{\text{Responses per reinforcer X Effort}}{\text{Magnitude of reinforcer}}$$

This equation can be used to generate the same unit price, even with varying values of the component figures. For example, to obtain a UP value of 10, a reinforcement schedule could require 10 responses to obtain 1 reinforcer. Alternatively, a requirement of 20 responses to obtain 2 units of the reinforcer would yield the same unit price. Hursh's inclusion of an effort term simply reflects the fact that, where relevant, force requirements could be factored in as an additional element of cost. Conceivably, many other factors also could contribute to the total cost of obtaining the reinforcing commodity.

According to some interpretations of behavioral economics, a given unit price, regardless of the component values, should produce the same level of consumption (DeGrandpre et al., 1993). This interpretation is interesting in that it suggests that response requirement and reinforcer value manipulations are functionally equivalent (Bickel, DeGrandpre, Hughes, & Higgins, 1991; DeGrandpre et al., 1993). However, this interpretation has recently been called into question by Madden, Bickel and Jacobs (2000), who investigated the effects of UP on consumption of cigarette puffs. In that study, different compositions of the same UP yielded different levels of consumption. More research on this point is required to determine why the supposed equivalence of unit price constituents does not hold under all circumstances.

Consumption is a basic dependent measure of behavior within the field of behavioral economics (Hursh, 1980). Bickel, DeGrandpre, Higgins, and Hughes (1990) defined consumption as the number of reinforcers contacted. Consumption is measured by multiplying the number of response requirement completions by the reinforcer

magnitude. Demand is described as the level of consumption at a given unit price. Demand is portrayed in the form of the demand curve that plots consumption against unit price; it is the most basic data analysis tool utilized in behavioral economic studies (Bickel, DeGrandpre, & Higgins, 1995). The demand curve is typically shown in log-log coordinates to represent proportional change (Hursh, 1984). Typically, as the UP increases, consumption decreases in a positively decelerating fashion (Allison, 1983). The Law of Demand is a concept adapted from economic theory that describes the phenomenon of decreasing consumption with increasing price. The rate at which consumption changes as a function of price is described as the elasticity of demand (Hursh, 1978, 1980, 1984; DeGrandpre et al., 1993; Bickel et al., 1995). Demand is said to be inelastic if the consumption of a commodity changes less than the proportional increase in price. The inverse, when decreases in the consumption of a commodity are greater than the proportional increase in price, is termed elastic demand. The degree of elasticity of demand for a commodity is quantified as the slope of the demand curve.

It is critical to note that elasticity is a description of demand and not an inherent property of the commodity or reinforcer (DeGrandpre et al., 1994). Much like the effectiveness of a commodity as a reinforcer, this property can and does vary widely. The elasticity of demand for a given commodity is known to vary based on several factors, such as the availability of other commodities, other sources of the same commodity, nature of the commodity (luxury or necessity), the species of the consumer, economic context, and the consumer's relative deprivation of the commodity (Hursh, 1984). For example, a food-deprived animal will typically exhibit inelastic demand for

food pellets and more elastic demand for non-nutritional luxury items (such as sucrose enriched water).

Several formulas have been proposed to calculate elasticity (see, e.g., Allison, 1983); however, they differ in only minor ways from the equation introduced by Samuelson and Nordhaus (1985):

$$\text{Elasticity} = \frac{\text{delta Q}}{(Q1+Q2)/2} \Big/ \frac{-\text{delta P}}{(P1+P2)/2}$$

In this equation, delta Q is the change in the quantity consumed, and Q1 and Q2 are the quantity consumed under UP 1 and UP 2, respectively. Delta P is the change in price and P1 and P2 are the first and second UP. If the elasticity coefficient resulting from this calculation is less than 1.0, then demand for the commodity between those prices is said to be inelastic. An elasticity coefficient greater than 1.0 represents elastic demand, with elasticity increasing with larger positive coefficients. Thus, an elasticity coefficient of 3.0 indicates an extreme sensitivity of consumption to price change. The elasticity of demand for a commodity is often "mixed", meaning that demand is relatively inelastic between some UPs and becomes elastic between other UPs. Therefore, elasticity coefficients are often calculated for each change in unit price (Bickel, Hughes, DeGrandpre, Higgins, & Rizzuto, 1992).

In most demand curves in which demand is inelastic or exhibits mixed elasticity, consumption remains relatively stable at lower unit prices. Increasing levels of responding are required to support the same consumption levels as unit price increases. This pattern of response (or work) output is described as the organism "defending" levels

of consumption. At some point, the work required to obtain the reinforcer seems to exceed the value of the reinforcer, and work output and therefore consumption levels rapidly decrease. The point of highest work output has been termed P-max, which corresponds to the point at which demand changes from being inelastic to elastic (Hursh, 1991, 1993).

Many commodities have been used in behavioral economic research, including various forms of food (Heyman & Tanz, 1995, Hursh, Raslear, Shurtleff, Bauman & Simmons, 1988, Foltin, 1994), water (Case, Nichols, & Fantino, 1995, Hursh, 1978), brain stimulation (Green & Rachlin, 1991), and various types of drugs. Hursh and Winger (1995) pointed out that many classes of drugs have been used in behavioral economic experiments. Examples include PCP, cocaine, opiates such as codeine (Hoffmeister, 1979), nicotine in the form of cigarettes (Bickel et al., 1991, Madden et al., 2000), and alcohol (Carroll, Carmona, & May, 1991, Bickel et al., 1995). Several species have been involved in behavioral economic research, including humans (Bickel et al., 1991), rats, pigeons, and monkeys (DeGrandpre, et al., 1993). This wide variety of reinforcers, procedures, and species all lend to the generality of behavioral economic theory.

DeGrandpre, Bickel, Higgins, & Hughes (1994) investigated demand for concurrently available cigarettes and money by humans to assess the economic properties of each commodity. Results showed that demand for money was more elastic than demand for cigarettes, and that changing levels of consumption of one commodity did not affect consumption levels of the other commodity. As stated by the authors, prior to the

DeGrandpre et al. (1994) study, no published research has examined the consumption of money as a commodity in the behavioral economic context. Given that money is used as a reinforcer in many human operant experiments (Pilgrim, 1998), it would seem prudent to investigate its economic properties further.

In the last several years, a series of experimental behavioral economic investigations has been conducted at the University of North Texas (Viken, 1999; Reyes, 2000; Alvey, 2000; and Bailey, 2001). This line of research has utilized money as a commodity and has been primarily concerned with methodological issues in human behavior economic research. Viken (1999) developed the basic experimental task (participants solving math problems for money) and studied the effects of different compositions of unit price on the consumption of money. Results indicated that demand decreased as UP increased, as predicted by the law of demand. Consumption became elastic for 3 subjects at different unit prices, ranging from between UP 4 and UP 6 to between UP 16 and UP 18. An insufficient number of exposures to alternate compositions of the same unit price did not permit conclusions to be drawn about the effect of manipulating UP composition.

Reyes (2000) suspected that the relatively high degree of inelasticity observed on the part of some participants in the Viken (1999) study could have been due to certain procedural aspects of the research. Reyes (2000) modified several elements of the experimental procedure, including adding a more active way for the participant to terminate a session and some changes in the instructions given to participants. Reyes utilized a factorial design across groups to examine the effects of fixed-ratio (FR) versus

variable-ratio (VR)-based unit prices and the effects of the presence or absence of a pre-session description of the current unit price. The results showed that, VR-based unit prices generally maintained higher levels of demand (greater inelasticity) than did FR-based prices. Providing descriptions of the unit price in effect had very little effect on demand under FR-based unit prices, but had a substantial effect in increasing the elasticity of demand under VR-based unit prices. For the VR-Description group, demand was similar to that observed in the two FR groups. The VR-No Description group produced the least elastic demand of any group.

Alvey (2000) examined own-price elasticity of demand for two qualitatively different reinforcers: sound clips and points exchangeable for money. The two commodities produced different degrees of elastic demand, with demand for sound clips decreasing more than demand for points/money in a second exposure to the sequence of FR-based unit prices. Bailey (2001) investigated the effects of the presence versus absence of a cumulative on-screen feedback bar that informed the subject of progress toward maximum pay out during the session. The feedback bar had been used in the study by Viken (1999) but not by Reyes (2000). Bailey's data suggested that earnings feedback could somewhat affect the elasticity of demand, although the differences in demand observed between the feedback and no-feedback groups were small and not statistically significant.

The study by Reyes (2000) also included a limited analysis of the effects of different unit price sequences. The comparison resulted when one group of participants was exposed to an erroneous FR-based unit price sequence in which one additional

session of UP1 was inserted into the sequence. Subsequently, an additional group was recruited and exposed to the correct unit price sequence. The two sequences compared were not planned and were thus a weak basis for drawing any conclusions about possible sequence effects. Nevertheless, slight differences in the elasticity of demand between the two groups exposed to different UP sequences suggested that the order of exposure to the range of unit prices might be a potent variable affecting consumption. Despite the fact that experiments in the behavioral economic literature have used different unit price sequences (some ascending/descending, some mixed sequences), no study has systematically examined possible sequence effects.

One might expect to see various types of effects based on alterations of unit price sequence. One possible aspect of UP sequence that could result in such effects is direction of UP change. For example, a change from UP 1 to UP 5 might have a different effect on demand than a change from UP 5 to UP1. The possibility of direction of UP change affecting elasticity was suggested by Reyes (2000), but not addressed adequately in the experimental design. Another potentially relevant dimension of UP sequence is the magnitude of change in UP (step size). Would demand at UP 10 be the same if the step size from the UP in effect during the preceding session was small or large? It is also possible that unit price might interact with the temporal proximity to milestones in the study (such as the beginning and the end of participation in the experiment) to affect demand. For example, might responding at a high UP early in the experiment be different from responding at that same UP later in the study? An analysis of demand under different unit price sequences can examine these possibilities.

CHAPTER 2

METHOD

Participants and Setting

Twelve undergraduate college students (10 female, 2 male) from the University of North Texas, ranging from 18-23 years of age, participated in this experiment. Participants A1, A2, A3, A4, B2, B3, B4, C1, C3 and C4 were female, and participants B1 and C2 were male. Each participant was assigned randomly to one of three experimental groups (Group A, B or C). Participants were recruited from introductory behavior analysis classes and an advertisement placed in the University newspaper. All participants were required to complete a series of pre-screening questionnaires to determine if they possessed any visual or motor impairments that could interfere with their performance. By means of paper and pencil worksheets, the participants were exposed to all of the multiplication problems that were used in the experiment and required to meet a minimum of 12 problems correct per minute in a 2 minute timed test on these problems with no more than 5 errors. All participants met the requirements for participation in the experiment.

The experiment took place in two University laboratory rooms, each of which contained a table with a personal computer, computer monitor, keyboard, mouse and a chair. The laboratory room was approximately 8 feet X 8 feet and contained a 2 way

mirror which was covered by closed mini-blinds. The participants were alone in the room during the sessions.

Apparatus

The apparatus consisted of an Intel Pentium-based 200 MHz IBM-compatible computer and a 100 MHz IBM-compatible computer (one in each room), each with keyboard and mouse. A computer program, written in-house in Visual Basic programming language, presented multiplication problems ranging from 1 X 1 to 10 X 10. The program selected and displayed each problem randomly without replacement, so that all 100 multiplication problems were presented before any problems appeared a second time. The problems appeared in 150 point Comic Sans Serif font on a gray screen with a space at the bottom used to display input from the keyboard (i.e., the answers to the problems). Answers to the problems were entered using either set of numbers on the keyboard. If the participant entered the incorrect answer, the text color of the math problem changed from black to red and remained on the screen until a correct answer was provided.

At the completion of each response requirement, the program presented a pre-recorded .wav file of a female voice stating, "5 cents". At the conclusion of each session, a screen displayed the amount earned in cents for that session. This screen appeared either when the participant earned the total amount possible for the session or when the participant terminated the session. Pressing the "Q" button on the keyboard at any time during the session terminated the session.

Dependent Variables

The dependent variables consisted of the total amount of responding and total consumption of money at each unit price, response rates per session, and session durations.

Independent Variable

The independent variables consisted of unit price structure, the presentation order of unit prices, and number of exposures to each unit price. Five unique unit price structures were created by altering the responses per reinforcer requirements. Each participant was exposed to each of the 5 unit prices; UP1, UP 6, UP 11, UP 16 and UP 21. The order of exposure to the unit prices depended upon the experimental group to which the participant was assigned to. The unit price progression for Group A was UP 1, UP 6, UP 11, UP 16, UP 21. The UP progression for Group B was UP 1, UP 11, UP 6, UP 16, UP 21. Group C was exposed to UP 1, UP 21, UP 6, UP 16, UP 11.

Subjects A4, B4, and C4 were exposed to each unit price only once; all other subjects were exposed to each unit price a second time in the same order as the first exposure.

Procedure

Participants could earn from $0.00 to $10.00 in 5-cent increments. The performance of the participant determined the amount of money earned in each session. All monies earned were paid at the end of each session. The participants also received a $25.00 bonus at the completion of the experiment if 2 passes (10 sessions) were

completed, or a $20.00 bonus in the cases of subjects A4, B4 and C4, who only completed 1 pass (5 sessions).

Participants were exposed to a pre-screening and training session followed by a minimum of 5 experimental sessions. In most cases, a maximum of one session was conducted per day. In each session, the participants earned money by solving multiplication problems. The target response consisted of entering the correct answer to the presented problem on either the numeric keypad or the number keys across the top of the keyboard, followed by pressing either enter key. Correct answers counted towards the current response requirement. Incorrect answers did not count towards the response requirement, nor was there any penalty for incorrect answers. Each completed response requirement earned 5 cents, coupled with the audio feedback, until the maximum of $10.00 was reached or the participant terminated the session.

Participant's responses or the maximum amount of money possible for the session determined session length. Participants had the option to terminate sessions at any time. If the participant did not terminate the session and continued to correctly solve problems, sessions ended when they earned the maximum amount of money for the session, which was always $10.00. No time limitations were placed on the participants to eliminate the possibility that time could elapse while the participant was still responding and artificially produce a decrease in consumption levels. Participants were allowed to take any number of 5-minute breaks at any point throughout the session. At the end of each session, participants signed a payment log and received full payment for that session. Bonuses earned were paid during the debriefing session following the last experimental session.

Pre-screening

During the initial pre-screening and training meeting with the participant, the experimenter read the following statements out loud:

> "The experiment you are about to participate in involves solving multiplication problems ranging from 1 X 1 to 10 X 10. Only one session will be conducted per day, and the total number of sessions will be around 10. You will earn a $25.00 (or, if appropriate, $20.00) bonus when you complete all of the sessions. Sessions must be scheduled for a time that will not conflict with other activities. For example, sessions should not be scheduled directly before a meeting or class time."

The participants were then asked to fill out several forms including a series of screening questions that inquired about possible handicaps that would interfere with the participant's interaction with the computer while alone in a small room. No participants were dismissed based on the results of these questions. The participants also completed a worksheet that included all one hundred problems included in the 1 X 1 to 10 X 10 range, in ascending order. The participants were allowed no more than 5 errors on this worksheet. The second worksheet included a random list of multiplication problems. The subject was informed that work on this task was to be timed, and told to begin. The subject answered as many questions as possible in two minutes. To be eligible for the study, the participant was required to answer at least 12 questions per minute with no more than 5 errors. No participants were dismissed based on the results of either of the math worksheets. The participants then read and signed an informed consent form.

Training

The training session mimicked an actual session in most ways. The only difference was that the maximum limit was set at twenty-five cents on a fixed ratio 1 (FR 1) schedule. The participant entered the experimental room, sat down in front of the computer, and was informed that a copy of the general experiment instructions was posted on the wall of the experiment room. The subject was instructed to follow along as the experimenter read the instructions aloud. These instructions read as follows:

> "In this experiment, you will have the opportunity to earn up to $10.00 every session. The way you can earn money is to work by solving math problems. The purpose of this study is to investigate choice. In each session, you will be able to choose to work as little or as much as you want. You can solve as few or as many math problems as you choose. If you choose to solve math problems, type in the answer using the numeric keypad and press the enter key. If the answer is correct, another problem will be presented on the screen. If the answer is incorrect, the problem will turn red, and will remain on the screen until a correct answer is provided. Incorrect responses will NOT count against you in any way. While solving the problems, you may notice a sound periodically informing you of the amount of money you have just earned. The computer will keep a running total of your earnings throughout each session. If you choose not to solve math problems, at any time after the session begins you may press the "q" button on the keyboard followed by the enter key and the session will terminate. There is no penalty for pressing the "q" button at any point throughout the session and you will be paid

the amount of money you have earned up to that point. You may also take short breaks (up to 5 minutes) at any point throughout the session to use the bathroom or to get a drink of water. Do not press "q" if you want to take a break, you may leave a problem presented on the screen until you return. When the session ends, a screen will appear telling you how much money you have earned and you may go inform the experimenter that you have finished. Please remember, there is no right or wrong way to respond. It makes no difference to the experimenter what you choose to do. The number of math problems you choose to solve is entirely up to you."

The participant was then told that the instructions would remain posted on the wall for the experiment's duration. The experimenter then read these additional instructions out loud:

"The purpose of this session is to familiarize you with the experiment. In this session, you will earn 25 cents. Normally, you will be able to earn up to $10.00. When you earn 25 cents the session will terminate. At this point, exit the room and find the experimenter. Please begin when I exit the room."

At this point the experimenter gave the participant an opportunity to ask questions regarding the procedures and then exited the room. After the subject earned 25 cents, the experimenter was contacted and the computer was reset for a new session while the participant waited in the hallway. When the computer was prepared, the participant was recalled and the experimenter read aloud this set of instructions:

"Now I would like you to practice ending the session. When the first problem is presented, terminate the session. You may refer to the instructions if necessary. I will remain in the room during this session."

In this second training session the subject pressed "Q" to terminate the session before working any problems, while the experimenter remained in the room. The subject then signed the payment log and received payment for money earned in the training session (25 cents). In this way the participants gained experience with all tasks required of them in the course of the experiment.

Unit Price Design

Unit prices in all conditions were composed using a constant reinforcer magnitude of 5 cents and a varying response requirement. A rectangular distribution of variation was generated by calculating 20% above and below the programmed response requirement. For UP 1, the required responses varied between one number above and one number below the programmed requirement of 5 responses, producing a range of 4 to 6 responses. The programmed response requirement at UP 6 was 30, with a range of 24 to 36. Following the same pattern, required responses for UP 11 had a range of 44 to 66, UP 16 had a range of 64 to 96, and UP 21 had a range of 84 to 126. The computer program selected values from these ranges without replacement. Once all values from the range were used one time, the program again began selecting from the entire range.

CHAPTER 3

RESULTS

Demand and work output were the focus of the data analysis. Demand curves were produced by plotting consumption in cents against increasing unit prices in log-log coordinates (see top graphs in Figures 2 - 13). The slope of the demand function illustrates the relationships between the variables of consumption and unit price. The elasticity coefficients displayed in the graphs, calculated according to a formula in Samuelson and Nordhaus (1985), show relative elasticity of demand between particular prices. Inelastic demand is indicated by coefficients less than 1.0 and elastic demand by coefficients greater than or equal to 1.0. Along this continuum of elasticity, coefficient magnitudes above 1.0 represent increasingly elastic demand.

Work output functions were produced by plotting total amount of responding against increasing unit prices in log-log coordinates (see bottom graphs, Figures 2 - 13), much like the demand function. The shape of this function shows how the total amount of responding modulates in reaction to UP changes. A bitonic function is typically obtained, resulting from defense of consumption as UP increases and demand is inelastic and decreasing response output as demand becomes elastic. The peak of the work output function corresponds to the price at which demand becomes elastic.

The rate of responding, expressed as the number of problems solved correctly per minute, was also calculated for each participant. These rates are shown in Figure 1.

Session duration also was calculated (see Figure 16) for each participant. Session durations that are constant across unit prices suggest that the participant may have been allocating a fixed period of time to each session. If the participant indeed did consistently terminate sessions after the same amount of time (e.g., 20 min), consumption would necessarily decrease as unit price increased. The shape of the resulting demand curve would be at least partially the result of a time limit imposed by the participant.

General Effects

Several effects could be seen consistently in all three experimental groups. Figure 1 shows that response rates increased over the course of the experiment for all participants. In most instances, at an individual unit price, response rates were higher in the second exposure. A similar effect had been observed in prior experiments utilizing the same experimental task (Bailey, 2001; Reyes, 2000). No distinguishable differences between groups were identified in rates of responding. For many participants, rates in session 6 (the second exposure to UP 1 for all participants) were elevated relative to rates in preceding or following sessions. Session 6 was preceded and followed by sessions with higher unit prices.

Demand curves and work output functions generally conformed to the pattern predicted by the Law of Demand for Groups A and B. Demand was inelastic between the lowest prices and elastic at the higher prices. The work output functions generally showed the bitonic pattern of increasing then decreasing response output. Consumption was lower in the second exposure to the unit prices in the majority of cases. Group C participants produced an anomaly in the demand curve that will be discussed below.

Group A (UP1, 6, 11, 16, 21)

Demand and work output functions for the 4 participants in Group A are shown in Figures 2 – 5. Data from the first and second exposures are shown, as well as the means of the two passes. Overall, the demand curves for these participants show relatively elastic demand. For all participants in Group A, after demand became elastic it remained so between all higher unit prices (see Table 4 for elasticity coefficients by group). Demand became elastic between UP 6 and UP 11 for participants A1, A2, and A4. Demand became elastic between UP 11 and UP 16 for participant A3.

Little variation in consumption data is seen between first and second exposure to each UP, with the exception of participant A1 (Figure 2). Recall that participant A4 (Figure 5) was only exposed to each unit price once. In thirteen of fifteen cases when a unit price was replicated, consumption was lower in the second exposure. The exceptions are participant A2 at UP 16 and A3 at UP 21, who show second exposure consumption slightly higher than first exposure consumption. Consumption levels for Group A fall into the 5 - 100 cent range at the highest unit price (UP 21). This level is lower than the consumption for all participants in Groups B and C at UP 21.

An unusual differential between consumption patterns in the first and second exposure to the unit prices was detected for participant A1. The first pass of exposures to each unit price reveals typical elastic demand, with consumption decreasing greatly as unit price increases. The second pass of exposures contains high consumption at UP 1, then virtually no responding at each of the elevated unit prices. In fact, at each unit price above UP 1 in the second exposure participant A1 responded only enough to contact the

first reinforcer delivery. The work output function for this participant shows that her response output increased just enough to meet the response requirement for one point delivery. It should be noted that participant A1 remarked in the debriefing session that she was attempting to create "less difficult" future sessions by responding very little in the final four sessions of the experiment, claiming that she believed that her behavior might adjust prices in subsequent sessions.

Session duration data (Figure 16) indicate that, typically, sessions were shorter at each unit price during the second exposure. Variability in session durations between prices suggest that no participant in Group A had created limitations on session duration.

Group B (UP 1, 11, 6, 16, 21)

Figures 6 – 9 show the demand and work output functions for the 4 participants in Group B. Overall, demand for money was characterized by mixed elasticity. Demand sometimes became inelastic at prices above which elastic demand had occurred (see Table 4). Demand first became elastic between UP 6 and UP 11 for participants B1, B2, and B3. Demand first became elastic between UP 11 and UP 16 for B4. Elasticity of demand varied for participants B2, B3, and B4 at higher prices. Participant B2 produced negative elasticity coefficients as consumption was higher at UP 16 and UP 21 than it had been at UP 11. In all cases, when a participant was exposed to a unit price a second time, consumption data on the second exposure was lower than or the same as consumption in the first exposure (see Table 2).

Consumption levels for Group B at the two highest unit prices are lower than consumption levels at UP 1, but these levels are still higher than consumption levels from

Group A at the same prices (see Table 2). Consumption levels for participants in Group B are higher than those of Group A in every case but one. Participant A3 produced consumption levels higher than that of Participant B2 at UP 16.

Session duration data for Group B reveals that duration fluctuated with unit price for B1, B2 and B3, and that session duration was typically shorter during the second exposure to the UP sequence (see Figure 16). Participant B4 typically remained in the sessions between 20 and 40 min, even in sessions with high unit prices. This pattern is different from the other participants in the group and may indicate that B4 had imposed a time limit of less than an hour for sessions.

Group C (UP 1, 21, 6, 16, 11)

Demand and work output functions for the 4 participants in Group C are shown in Figures 10 - 13. Overall, the demand curves reveal mixed elasticity. Demand first became elastic between UP 6 and UP 11 for C2, C3 and C4; and between UP 11 and UP 16 for participant C1. This is similar to the pattern of initial elasticity observed in Groups A and B. In thirteen of fifteen cases where a participant was exposed to a unit price a second time, consumption was the same or lower in the second exposure (see Table 3). The exceptions were participants C1 and C2, whose consumption was higher in the second exposure to UP 16.

Perhaps the most striking feature of the demand curves for all participants in Group C is the negative elasticity observed at UP 21. Consumption at UP 21 was higher than at UP 16 in all cases during the first exposure to UP 21 (which occurred in the second session for these participants). In fact, first pass consumption at UP 21 is higher

than first pass consumption at both UP 16 and UP 11 for 3 out of the 4 participants (C2, C3, and C4). Participants C1, C2, and C3 were exposed to UP 21 again in session 7. Two participants (C2 and C3) consumed far less in the second exposure to this UP, whereas C1 consumed a nearly identical number of cents as in the first pass (see Table 3).

Session durations for Group C are shown in Figure 16. The data shows variation between sessions for most participants, with durations generally shorter in the second exposures to prices. Session durations stabilized somewhat in the last 5 sessions for Participant C3, which could indicate a self-imposed time limit on session length. It should be noted that this participant's final 5 sessions were conducted in a rapid succession over 2 days because of schedule constraints imposed by impending final examinations.

Between Group Comparisons

Figure 14 shows demand curves derived from the means of the first and second exposures to price for participants. Data from the fourth participant in each group was excluded because these individuals were not exposed to the price sequences a second time. Figure 14 enables convenient comparisons of the average demand curves across groups.

Differences in the details of the demand curves can be seen. Group A participants show the most elastic demand, with consumption decreasing substantially as unit price increases. Group B and C participants show more variation, but generally less elasticity (shallower decreases in consumption). Group C produced atypical elevated consumption at UP 21.

As in previous thesis studies from the same laboratory, a repeated-measures ANOVA was utilized to statistically examine group differences (see, e.g., Reyes, 2000). According to this test, the main effect for groups (this collapses the consumption data across unit prices to compare aggregate means) yielded an $F(1, 2)=3.967$, $p = .0799$, which would be significant if a lenient alpha level of .10 were used instead of the more common .05 level. However, the most appropriate test is not the main effect but the interaction effect of unit price by group (which compares the groups price by price). This effect yielded a nonsignificant $F(1, 8) = 1.339$, $p = .2725$. It should be noted that an ANOVA is a fairly strict test with such a small N (each group had only 3 participants). In a test computation, adding just one more subject to each group (duplicating A1, B1, and C1 data) would yield significant results at the .05 level for main effect and interaction effects.

Figure 15 shows the group mean consumption at each unit price. This equal interval histogram enables comparison of consumption levels across groups without the visual compression and expansion produced by the logarithmic plots in the demand curves. All three groups produced similar consumption levels at UP 1. Only Group A averages less than the maximum earnings, because one participant consumed less than the maximum on the second UP 1 exposure. Group A's consumption was the lowest of the groups at each higher price. In contrast, Group B's consumption was consistently higher than the other two groups at each price above UP 1. Group C averaged higher consumption than Group A at UP 6, but consumption was similar to Group A at UP 11 and 16, diverging again only when average consumption increased at UP 21.

The price sequences for each group were designed to enable some comparison points across groups. For example, Group A stepped up from UP 6 to UP 11 in sessions 2 and 3 whereas Group B stepped down in those same sessions from UP 11 to UP 6 (identical step size, opposite step direction). One way to compare these two step directions is to examine the proportional change between UP 6 and UP 11. Group A's mean consumption at UP 6 decreased by 58.9% at UP 11 whereas Group B's mean consumption at UP 6 decreased by 62.1% at UP 11. Group B showed a larger difference between these two prices than does Group A, due in large part to Group B's high consumption level at UP 6 (visible in Figure 15). Group C also stepped down to UP 6 from a higher price (UP 21). It is noteworthy that Group C's mean consumption at UP 6 was also above that of Group A.

Another comparison point between groups was UP 16. All three groups encountered UP 16 in the same ordinal position in the sequence of sessions (in the fourth and ninth sessions). This enabled the group's performances to be compared at the same unit price at the same point in the experiment. The only difference between the groups, then, was the preceding prices to which they were exposed. While the mean consumption of Groups A and C were similar at UP 16, that of Group B is elevated at this anchor point (see Figure 15).

Groups A and B encountered both UP 16 and UP 21 as successive sessions in the same ordinal position in the experiment. The differences in consumption observed between the two groups at UP 16 are repeated to a similar degree at UP 21. Group B's mean consumption is higher than Group A at UP 16 (213.3 vs. 61.7 cents) and at UP 21

(140.7 vs. 34.2 cents). Because both groups began the experiment at UP 1, the groups differed only in that Group A was exposed to the ascending sequence of UP 6 and UP 11 prior to UP 16 whereas Group B was exposed to UP 11 then UP 6 prior to UP 16.

Obtained Unit Price

Table 5 shows the variation between obtained unit price and programmed unit price for each participant, calculated as work output divided by consumption for each session. This variation becomes an issue of concern when utilizing a variable ratio schedule of reinforcement as the basis for generating unit price. VR schedules can produce obtained reinforcement schedules that are different from programmed schedules, especially if few reinforcers are consumed at a particular UP, and at higher unit prices when the distribution around each programmed price overlap. These issues become important if and when two obtained unit prices are closer in proximity than intended, diminishing the participant's ability to discriminate between unit prices. If there is a significant difference between obtained unit price and programmed unit price, this must be considered when interpreting consumption data.

As seen in Table 5, there were instances when differences occurred between the programmed unit price and the actual unit price obtained by the participant.

For Group A, there were 6 instances when the obtained unit price differed from the programmed unit price by more than 1. This variance can be seen for participant A1 at UP 6, UP 16, and UP 21 in the second pass, and participant A2 at UP 21 in the first pass and UP 16 and UP 21 in the second pass. This variance can be seen in Group B in the data of participant B2 at UP 21 in the second pass and participant B4 at UP 16 and UP

21. Finally, this variance is also seen in the data for Group C. Participant C1 at UP 16 in the first pass has this variance as does participant C2 at UP 16 in the first pass and UP 21 in the second pass, and participant C3 at UP 11 in the second pass. Despite these variances in obtained versus programmed unit price, in no case did an obtained unit price overlap with a lower or higher obtained unit price.

CHAPTER 4

DISCUSSION

The Law of Demand states that as the price for a particular commodity increases, consumption of that commodity will decrease (see Bickel et al., 1992). The demand curves produced by participants in all three sequence groups in this study conform to that law in the most general sense. Demand was higher at UP 1 than it was at UP 21 in all cases. However, there were differences in the elasticity of demand across groups as well as local deviations from the demand law at particular prices in some of the groups. The differences between the behavior of the participants in the three groups may be attributable to sequence effects. That is, the sequence of exposure to various unit prices may affect demand, a phenomenon first suggested by Reyes (2000).

Demand for members of Group A, who were exposed to the straight ascending price sequence, was more elastic than the relatively inelastic demand of Group B, who were exposed to a slightly jumbled sequence of unit prices. Group A participants produced the lowest levels of consumption at UP 21 of all participants. Demand for Group C participants resembled that of Group A, but departs in that consumption at UP 21 was at levels similar to those of Group B. It appears that being exposed to a simple ascending series of unit prices leads participants to consume fewer reinforcers at high prices than participants exposed to varied sequences of unit prices.

It is possible that any deviation from an ascending price series may make demand less elastic, although the behavior of Group B participants suggests that exposure to

moderately high prices early in the sequence (UP 11 in session 2) may be a factor responsible for reducing elasticity. When comparing Group A and Group B, the only difference between the two sequences was the reversal of the order of exposure to UP 6 and UP 11, yet consumption levels for these two groups were different at UP 16 and UP 21. Group B's consumption was higher than that of Group C at UP 16 (the common anchor point). The only procedural difference between the groups in the first pass was the exposure to the moderate UP 11 in session 2 for Group B and the exposure to the extreme UP 21 in session 2 for Group C. Being exposed to UP 21 early in the experiment led to the elevated demand at that price, but it may have also affected demand at several other unit prices. These effects suggest that the magnitude, as well as the ordering of prices in a varied price sequence, can affect demand.

There are a number of specific effects within each sequence that deserve closer scrutiny. What accounts for the abnormally elevated demand at UP 21 for Group C? There are two possible causes for this anomaly. One potential cause is a simple "early in the experiment" effect. It is a common observation in many experimental contexts that participants are quite punctual and hard working in early sessions of an experiment. As the experiment wears on, these behavior tend to diminish, perhaps because contact with the experimental contingencies begins to overwhelm the importance of the participant making a good social impression on the experimenter. A second potential cause for the elevated consumption at UP 21 in Group C is that this unit price was encountered immediately after UP 1, the experimental condition with the richest reinforcement frequency. Perhaps some sort of momentum effect (see Nevin, 1995) is responsible for

the elevated consumption at UP 21. That is, responding had been richly reinforced in the previous session, and this history may have facilitated sustained effort in the reinforcer-lean environment of UP 21 in the succeeding session.

The data from the first and second exposures to UP 21 can help support or refute these possible explanations (see Figures 10-13). All four participants of Group C showed elevated consumption at UP 21 in the first exposure. However, in the second exposure to UP 21 (session 7), only Participant C1 continued to show elevated demand (consistent with a momentum effect). The demand for participants C2 and C3 decreased substantially in the second pass, suggesting that the first pass elevation at UP 21 was due to its proximity to the beginning of the experiment. These data support both explanations for the elevated demand and therefore suggest that more than one factor can play a role in producing a particular sequence effect.

Comparisons of performances at programmed sequence comparison points can also shed light on the nature of sequence effects. The direction of change in unit price within the sequence may have an effect on consumption level. Step direction was isolated in the case of the unit price change between UP 6 and UP 11. Group A was exposed to UP 6 then UP 11, while Group B was exposed to UP 11 then UP 6. Stepping *down* in unit price from UP 11 to UP 6 may have been responsible for Group B participants' higher consumption levels at UP 6 relative to the behavior of Group A participants who stepped *up* from UP 6 to UP 11. The effect could be due to the immediate contrast in reinforcement frequency from one session to the next: UP 6 involves an increase in reinforcement frequency when it followed a UP 11 session. A

similar effect has been observed in experiments studying behavioral contrast, in which one component of a multiple schedule either increases or decreases reinforcement frequency and a contrasting effect of response rate is observed in another unchanged component of the schedule (see Catania, 1961; Dougan, McSweeney, & Farmer-Dougan, 1986; Reynolds, 1961). If one views successive sessions as being similar to temporally distributed components of a multiple schedule, the phenomenon of increased consumption following a transition from higher to lower price may be related to behavioral contrast.

Group C transited from UP 21 to UP 6, an opportunity for a contrast effect to lead to enhanced consumption at UP 6. Mean consumption for Group C at UP 6 was higher than Group A, but lower than Group B. If there was an effect of contrast, it was very slight. Perhaps other factors interacted with the contrast in reinforcement frequency to offset its effects.

Sequence effects also may be seen in the response rate data. Across all three groups, rates in session 6 (second exposure to UP 1) were higher than the preceding session and, in most cases, the following session. The effect could be due to the immediate contrast in reinforcement frequency from one session to the next; UP 1 yields a higher reinforcement frequency than the higher unit prices participants were exposed to in preceding and following sessions.

This study has shown that the sequence of exposure to a range of unit prices can affect demand and response rates. Although the differences between groups were not always large, some differences are almost certainly due to sequence, barring the

alternative explanation that group differences are simply the result of the limited number of participants in each group. The latter possibility can only be addressed by replication studies. A caveat is in order regarding the range of unit prices used in this study. When compared to unit prices examined in drug studies, in which unit price varies by several orders of magnitude, the range of prices used here is fairly narrow. Whether sequence effects would occur in studies with larger unit price ranges is not known.

The implications of unit price sequence effects for the experimental analysis of behavioral economic variables are several. First, sequence effects have practical implications for the design of experiments. When more is learned about sequence effects, it may be possible to design unit price sequences that will generate greater or lesser degrees of elasticity. That would be a powerful tool for the basic researcher. The applied practitioner may also benefit with new ways to improve transitions between schedules of reinforcement. Second, sequence effects may expand our understanding of the role of unit price in determining demand. Sequence effects suggest that demand at a particular unit price is in part determined by the context of the unit price in the organism's recent history of unit price exposures. Contextual effects on demand are well known in behavioral economics (e.g., the influence of closed or open economies), but they are usually discussed as the influence of concurrent contexts, not historical contexts. Sequence effects reveal an influence of recent history on subsequent behavior. They are found in many areas of study, including multiple schedule interactions yielding behavioral contrast effects as well as carryover effects seen in applied research designs (see Hersen & Barlow, 1984). To date, sequence effects have not been reported or

analyzed in behavioral economics. This experiment represents a first step in the process of that analysis. Continued research on this topic may expand our understanding of the complex relationship between the costs and benefits of behavior.

APPENDIX A

SCREENING QUESTIONS, MULTIPLICATION TESTS, DEBRIEFING QUESTIONS, AND INFORMED CONSENT FORM

Initial Participant Survey

Name of Participant: _____

Date of Birth: _____

Name of Experimenter: _____

1. Do you have the ability to look at a computer screen for an extended period of time?

   Yes _____ No _____

2. Do you have any problems using your hands to work on a computer?

   Yes _____ No _____

3. Can you read small text on a computer screen?

   Yes _____ No _____

4. Do you have any inhibitions to work in a room by yourself?

   Yes _____ No _____

5. Do you have extended understanding of behavior analytical basic research?

   Yes _____ No _____

6. Do you have any commitments following the times that you have signed up for that may conflict with your participation?

   Yes _____ No _____

_____ _____

Participant's Signature/Date Experimenter's Signature/Date

Screening Math Problems

NAME: _____

1x1=	**2x1=**	**3x1=**	**4x1=**	**5x1=**
1x2=	**2x2=**	**3x2=**	**4x2=**	**5x2=**
1x3=	**2x3=**	**3x3=**	**4x3=**	**5x3=**
1x4=	**2x4=**	**3x4=**	**4x4=**	**5x4=**
1x5=	**2x5=**	**3x5=**	**4x5=**	**5x5=**
1x6=	**2x6=**	**3x6=**	**4x6=**	**5x6=**
1x7=	**2x7=**	**3x7=**	**4x7=**	**5x7=**
1x8=	**2x8=**	**3x8=**	**4x8=**	**5x8=**
1x9=	**2x9=**	**3x9=**	**4x9=**	**5x9=**
1x10=	**2x10=**	**3x10=**	**4x10=**	**5x10=**

6x1=	**7x1=**	**8x1=**	**9x1=**	**10x1=**
6x2=	**7x2=**	**8x2=**	**9x2=**	**10x2=**
6x3=	**7x3=**	**8x3=**	**9x3=**	**10x3=**
6x4=	**7x4=**	**8x4=**	**9x4=**	**10x4=**
6x5=	**7x5=**	**8x5=**	**9x5=**	**10x5=**
6x6=	**7x6=**	**8x6=**	**9x6=**	**10x6=**
6x7=	**7x7=**	**8x7=**	**9x7=**	**10x7=**
6x8=	**7x8=**	**8x8=**	**9x8=**	**10x8=**
6x9=	**7x9=**	**8x9=**	**9x9=**	**10x9=**
6x10=	**7x10=**	**8x10=**	**9x10=**	**10x10=**

Screening Math Problems

NAME: _____

5 x 6=	**10 x 8=**	**6 x 7=**
7 x 8=	**7 x 4=**	**7 x 10=**
1 x 3=	**5 x 2 =**	**8 x 9=**
3 x 6=	**1 x 8=**	**2 x 2=**
8 x 2=	**3 x 9=**	**8 x 5=**
10 x 5=	**9 x 7=**	**7 x 7=**
6 x 7=	**8 x 3=**	**10 x 3=**
9 x 5=	**6 x 3=**	**1 x 6=**
2 x 2=	**4 x 4=**	**3 x 7=**
4 x 9=	**2 x 10=**	**5 x 1=**
2 x 8=	**9 x 1=**	**4 x 2=**
5 x 7=	**3 x 4=**	**7 x 3=**
2 x 4=	**10 x 2=**	**6 x 6=**
8 x 7=	**8 x 1=**	**1 x 4=**
9 x 10=	**4 x 8=**	**10 x 6=**
10 x 10=	**1 x 2=**	**10 x 6=**
2 x 9=	**8 x 4=**	**4 x 2=**
5 x 5=	**7 x 5=**	**7 x 3=**
8 x 9=	**9 x 8=**	**6 x 6=**
4 x 6=	**6 x 10=**	**1 x 4=**
3 x 3=	**2 x 1=**	**3 x 10=**
4 x 7=	**1 x 5=**	**6 x 8=**
7 x 10=	**5 x 3=**	**5 x 6=**
8 x 6=	**3 x 10=**	**4 x 10=**
9 x 9=	**6 x 5=**	**6 x 6=**
5 x 8=	**10 x 9=**	**1 x 1=**
7 x 6=	**8 x 5=**	**6 x 8=**
3 x 1=	**6 x 1=**	**7 x 9=**
6 x 4=	**4 x 3=**	**3 x 8=**
8 x 8=	**1 x 5=**	**5 x 9=**
10 x 4=	**10 x 7=**	**9 x 2=**
3 x 2=	**6 x 9=**	**10 x 8=**
4 x 5=	**4 x 1=**	**2 x 6=**
9 x 2=	**1 x 10=**	**4 x 7=**
2 x 6=	**3 x 5=**	**7 x 1=**

Debriefing Questions

1. What do you think the purpose of this experiment is?

2. What made you decide how much money you would earn?

3. Did you have prearranged plans for how you would spend any money you earned in this experiment?

4. How important was it for you to earn the money?

5. What was the main motivator for you to complete the experiment?

6. Did you at any point want to stop coming to the experiment?

7. Did you ever run out of time or get in a rush for other things while you were participating in the experiment?

8. What did you usually do after you finished the sessions?

9. Were the number of math problems you needed to solve to get the five cents always the same? If you did notice a change, did you notice any pattern (increasing, decreasing, up/down, etc) in the way it changed?

10. Any suggestions for things the experiment administrator could do to make the experiment easier or otherwise better for you? (For example, scheduling issues.)

Informed Consent Form

My name is J Keith Williams, and I am a graduate student at the University of North Texas. I am requesting your consent to participate in a research study. The results from this study may be presented at a conference.

Please read the following consent from carefully before signing.

Participant Consent Form

I understand that taking part in this experiment will last for a minimum of 10 sessions (approximately 2-3 weeks). Only one session will be conducted each day of participation. I will earn varying amonts of money during sessions for solving math problems on a computer and will obtain a $25 bonus upon completion of the 10 sessions. After the experiment I will be debriefed and be able to ask questions regarding the experiment. Benefits of participation include the potential for earning money during every session and a $25 bonus for completing the experiment. There are no forseen risks as a result of participating in this study.

I have been informed that any information obtained in this experiment will be coded by use of arbitrary numbers and the data will be kept locked up without access to anyone but the experimenters. Under these conditions, I agree that any information obtained in the study may be subject for publications and public presentations. Participation in this study is voluntary and I have the right to view my data at the conclusion of the experiment and determine to discontinue my participation at any time without penalty, prejedice or loss of benefits.

If I have any questions or problems that arise in connection with the participation in this study, I will contact Keith Williams at (940) 483-1220 or Dr. Cloyd Hyten at (940) 565-4071 (Department of Behavior Analysis).

Name of participant (please print) _____

_____ _____

Date Signature of Participant

_____ _____

Date Signature of Principle Investigator

This project has been reviewed and approved by the UNT Human Subjects Review Board

APPENDIX B

TABLES

Table 1. Unit price sequence (including replications) for all participants

Group	UP - Sequence	Sessions
Group A		
A1	1, 6, 11, 16, 21, 1, 6, 11, 16, 21	10
A2	1, 6, 11, 16, 21, 1, 6, 11, 16, 21	10
A3	1, 6, 11, 16, 21, 1, 6, 11, 16, 21	10
A4	1, 6, 11, 16, 21	5
Group B		
B1	1, 11, 6, 16, 21, 1, 11, 6, 16, 21	10
B2	1, 11, 6, 16, 21, 1, 11, 6, 16, 21	10
B3	1, 11, 6, 16, 21, 1, 11, 6, 16, 21	10
B4	1, 11, 6, 16, 21	5
Group C		
C1	1, 21, 6, 16, 11, 1, 21, 6, 16, 11	10
C2	1, 21, 6, 16, 11, 1, 21, 6, 16, 11	10
C3	1, 21, 6, 16, 11, 1, 21, 6, 16, 11	10
C4	1, 21, 6, 16, 11	5

Table 2. Total consumption (C) in cents and work output (W) in number of responses at every unit price for all participants in Groups A and B. First and second exposure to each price are shown in rows.

Group A

Programmed Unit Price	A1	A2	A3	A4	A1	A2	A3	A4
	C	C	C	C	W	W	W	W
UP 1 (5/5)	1000	1000	1000	1000	1001	1001	1000	1000
	1000	785	1000		1001	786	1000	
UP 6 (30/5)	1000	340	310	350	6001	2033	1858	2098
	5	270	240		24	1622	1442	
UP 11 (55/5)	50	250	335	125	551	2739	3717	1369
	5	40	210		55	440	2319	
UP 16 (80/5)	15	20	180	30	251	312	2924	472
	5	25	125		70	359	1988	
UP 21 (105/5)	5	20	75	20	104	460	1647	416
	5	10	90		94	183	1899	

Group B

Programmed Unit Price	B1	B2	B3	B4	B1	B2	B3	B4
	C	C	C	C	W	W	W	W
UP 1 (5/5)	1000	1000	1000	1000	1001	1001	1000	1000
	1000	1000	1000		1001	1000	1001	
UP 11 (55/5)	500	105	415	125	5501	1155	4611	1373
	415	15	225		4592	152	2476	
UP 6 (30/5)	1000	835	760	215	5999	5004	4553	1300
	1000	355	465		6004	2121	2786	
UP 16 (80/5)	325	90	325	40	5215	1419	5199	585
	260	85	195		4108	1316	3173	
UP 21 (105/5)	215	280	105	40	4515	5852	2213	792
	135	15	95		2816	286	1963	

Table 3. Total consumption (C) in cents and work output (W) in number of responses at every unit price for all participants in Group C. First and second exposure to each price are shown in rows.

Group C

Programmed Unit Price	C1	C2	C3	C4	C1	C2	C3	C4
	C	C	C	C	W	W	W	W
UP 1 (5/5)	1000	965	1000	1000	1000	966	1001	1000
	1000	1000	1000		1001	1000	1001	
UP 21 (105/5)	165	195	215	150	3496	4081	4515	3107
	155	10	30		3271	221	623	
UP 6 (30/5)	505	1000	330	570	3042	6000	1985	3413
	500	345	135		3005	2067	812	
UP 16 (80/5)	35	20	45	50	617	367	703	810
	110	110	40		1726	1745	644	
UP 11 (55/5)	290	70	150	60	3202	749	1629	673
	285	10	40		3151	109	481	

Table 4. Elasticity coefficients for all participants. Shaded areas indicate elastic demand.

		Unit Price Changes			
		1 - 6	6 - 11	11 - 16	16 - 21
Group A	A1	0.46	3.05	2.52	2.47
	A2	0.69	1.21	3.95	1.48
	A3	0.79	0.02	1.52	2.20
	A4	0.67	1.61	3.31	1.48
Group B	B1	0.00	1.27	1.19	1.86
	B2	0.36	2.78	-1.01	-1.89
	B3	0.34	1.07	0.56	3.29
	B4	0.90	0.90	2.78	0.00
Group C	C1	0.46	0.93	3.23	-2.78
	C2	0.26	3.02	-1.29	-1.66
	C3	0.87	1.43	2.06	-3.59
	C4	0.38	2.75	0.49	-3.70

Table 5. Programmed unit price (shown in white) and actual obtained unit price (shown in shaded area) for each session.

A1		A2		A3		A4	
1	1.00	1	1.00	1	1.00	1	1.00
6	6.00	6	5.98	6	5.99	6	5.99
11	11.02	11	10.96	11	11.09	11	10.95
16	16.73	16	15.60	16	16.24	16	15.73
21	20.80	21	23.00	21	21.96	21	20.80
1	1.00	1	1.00	1	1.00		
6	4.80	6	6.01	6	6.01		
11	11.00	11	11.00	11	11.04		
16	14.00	16	14.36	16	15.90		
21	18.80	21	18.30	21	21.10		

B1		B2		B3		B4	
1	1.00	1	1.00	1	1.00	1	1.00
11	11.00	11	11.00	11	11.11	11	10.98
6	5.99	6	5.99	6	5.99	6	6.05
16	16.05	16	15.77	16	15.99	16	14.63
21	21.00	21	20.90	21	21.08	21	19.80
1	1.00	1	1.00	1	1.00		
11	11.07	11	10.13	11	11.00		
6	6.00	6	5.97	6	5.99		
16	15.80	16	15.48	16	16.27		
21	20.86	21	19.07	21	20.66		

C1		C2		C3		C4	
1	1.00	1	1.00	1	1.00	1	1.00
21	21.19	21	20.93	21	21.00	21	20.71
6	6.02	6	6.00	6	6.02	6	5.99
16	17.63	16	18.35	16	15.62	16	16.20
11	11.04	11	10.70	11	10.86	11	11.22
1	1.00	1	1.00	1	1.00		
21	21.10	21	22.10	21	20.77		
6	6.01	6	5.99	6	6.01		
16	15.69	16	15.86	16	16.10		
11	11.06	11	10.90	11	12.03		

APPENDIX C

FIGURES

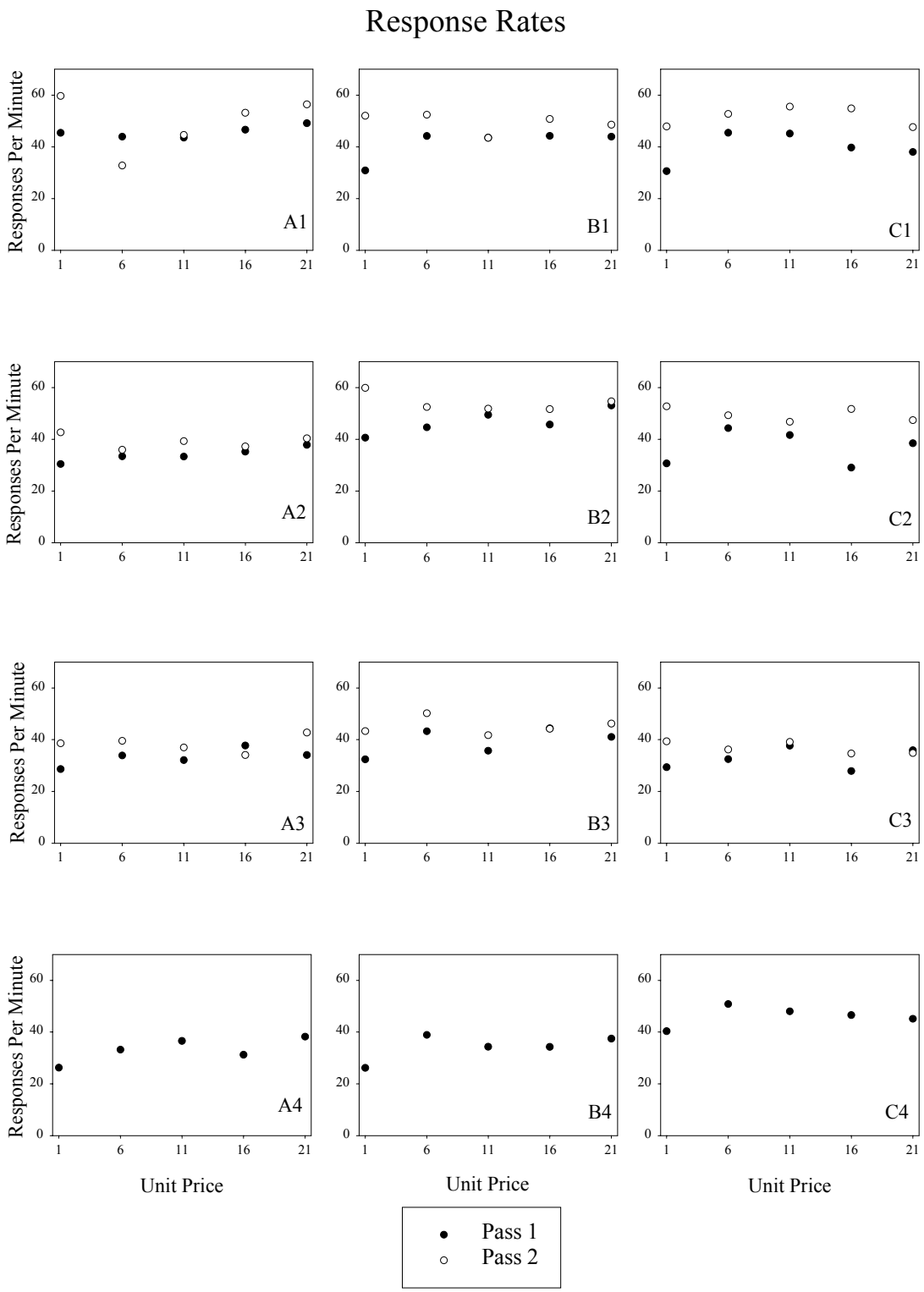


Figure 1. Correct Responses Per Minute plotted by session number.

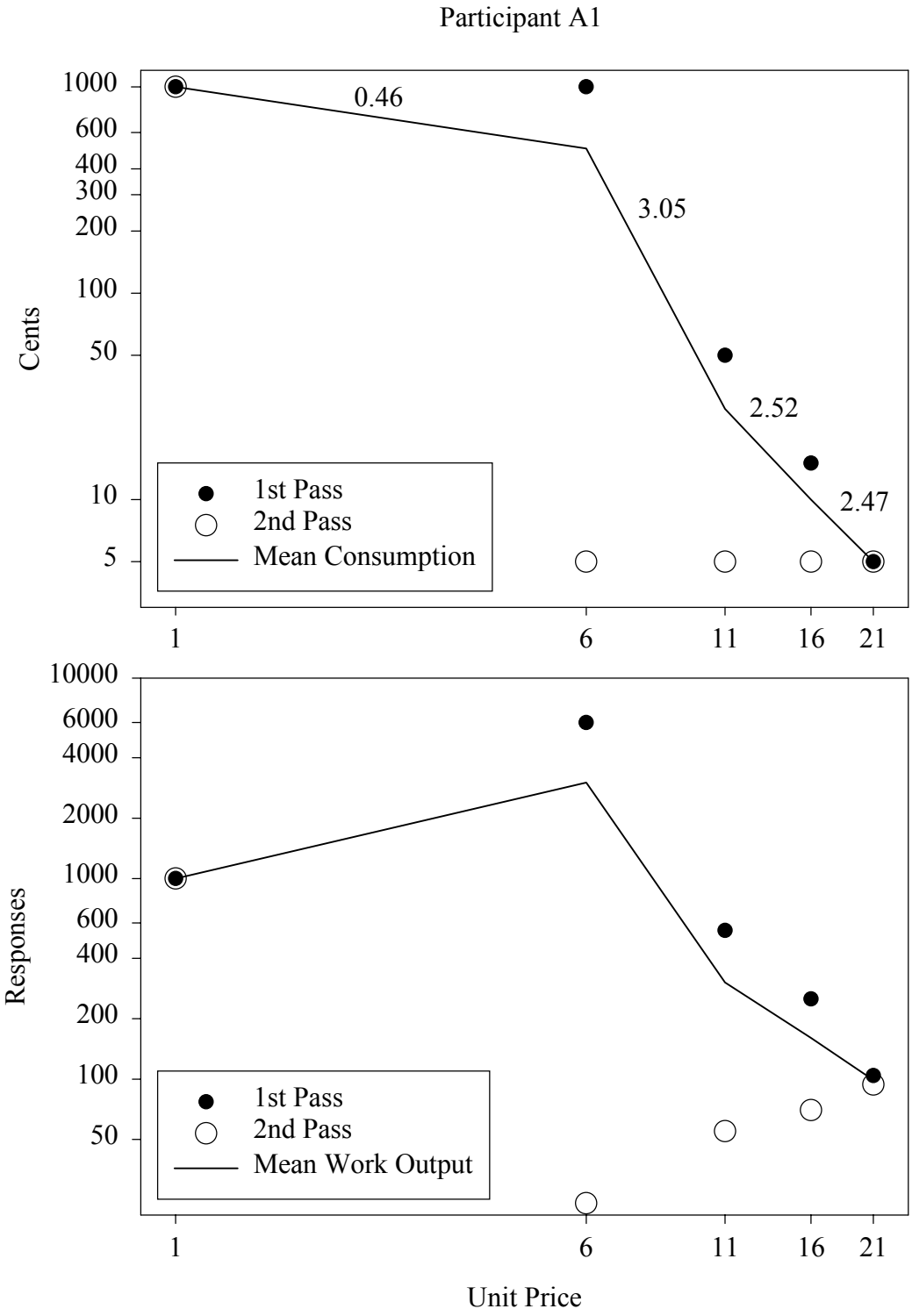


Figure 2. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

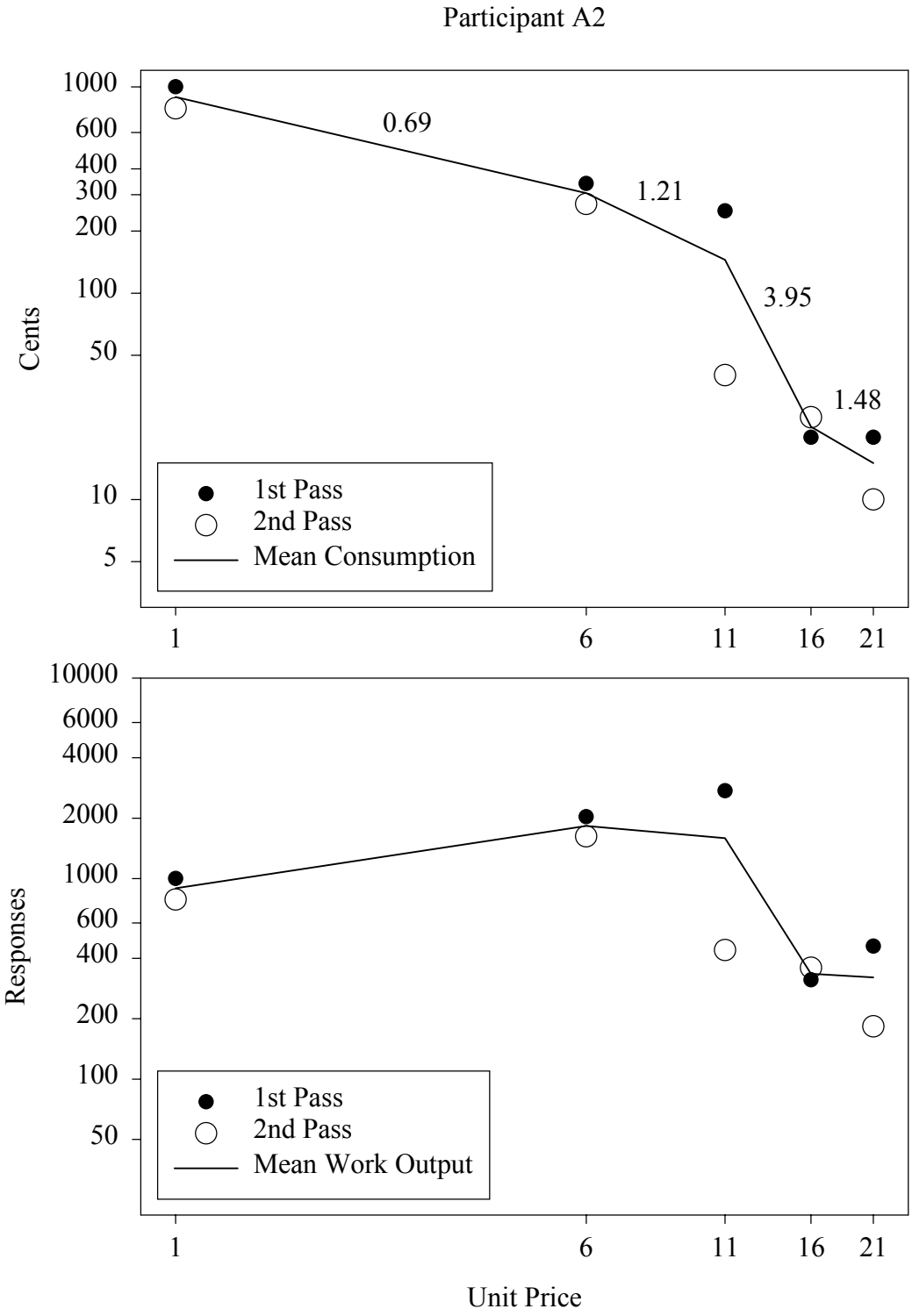


Figure 3. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

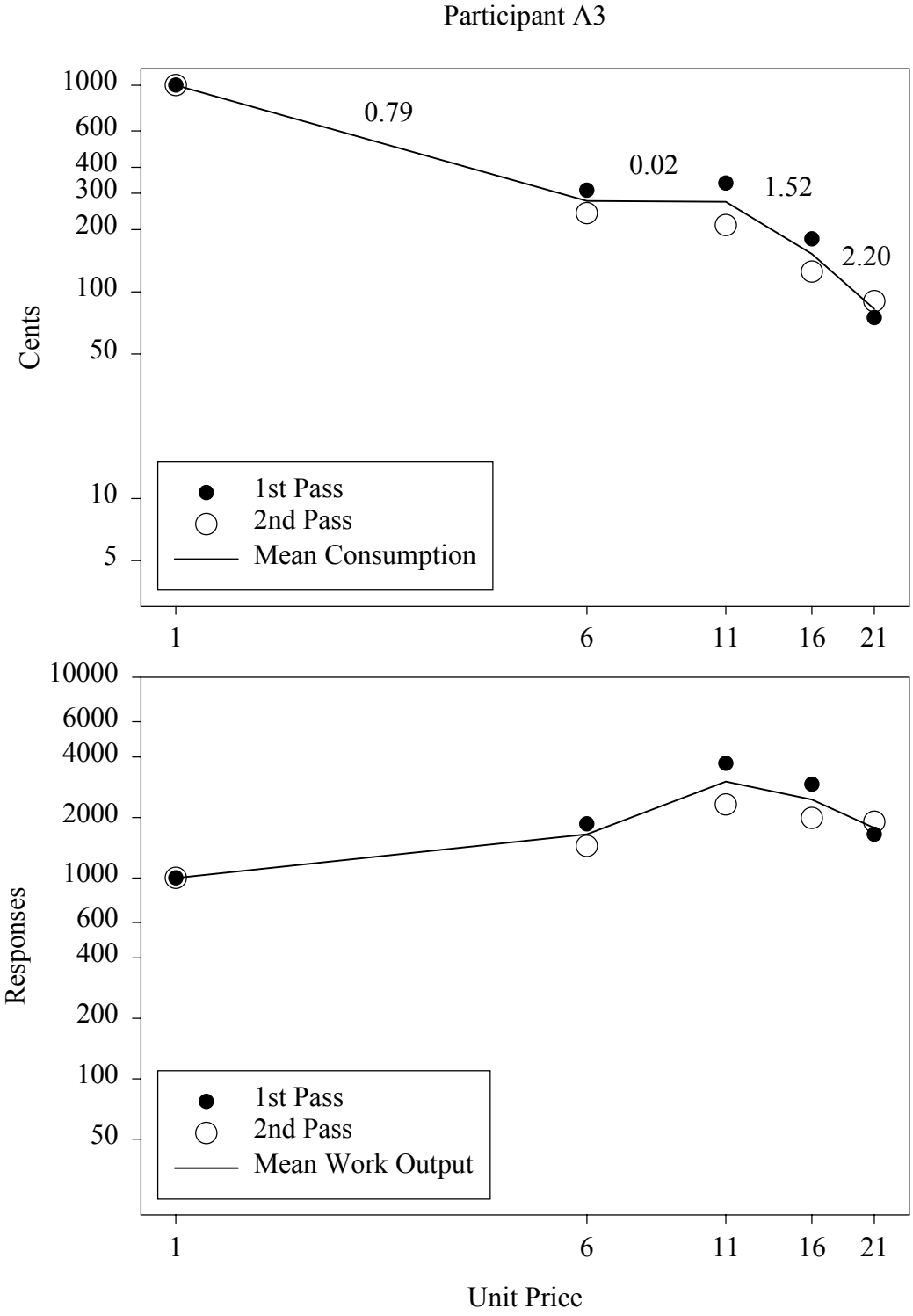


Figure 4. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

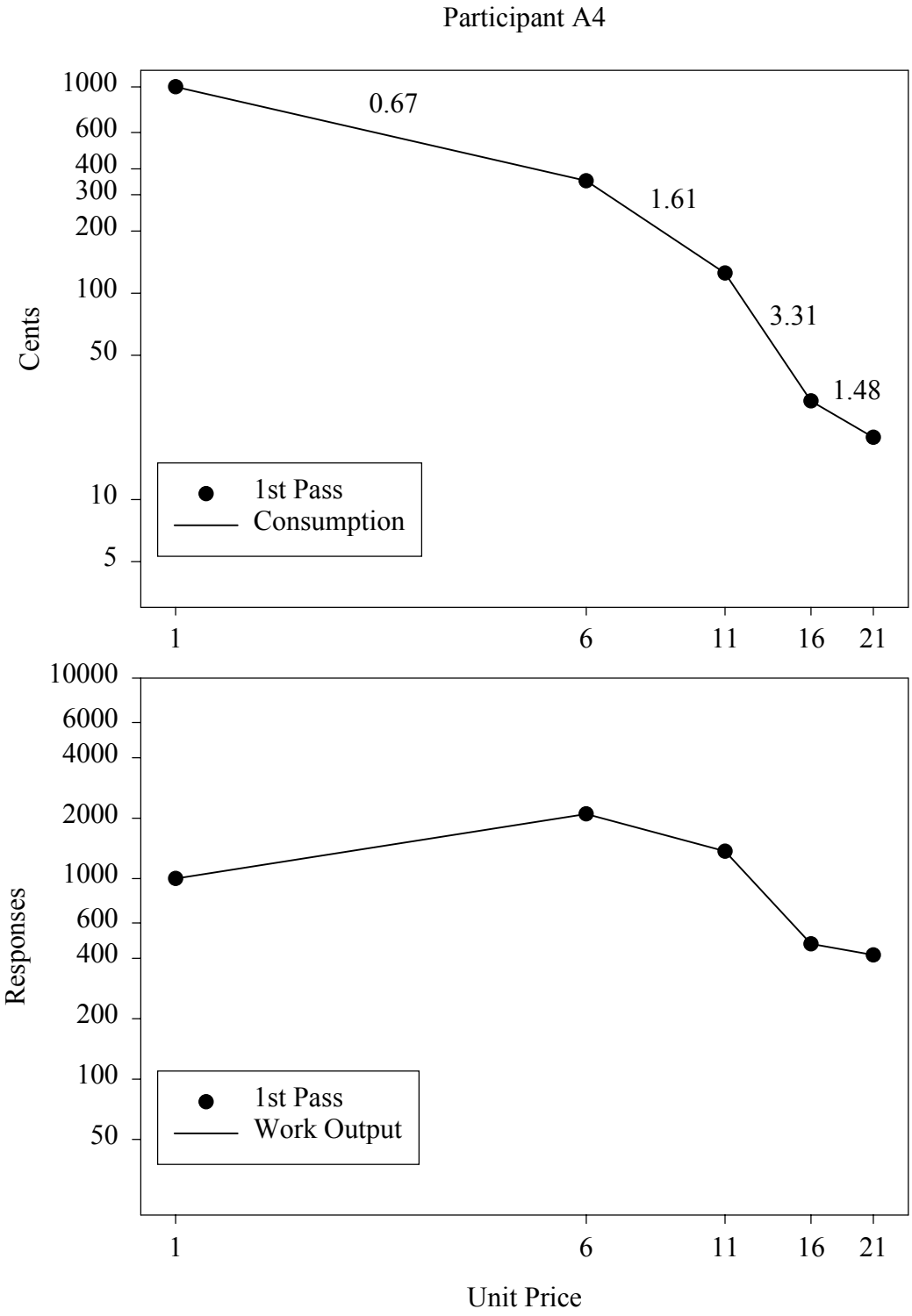


Figure 5. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

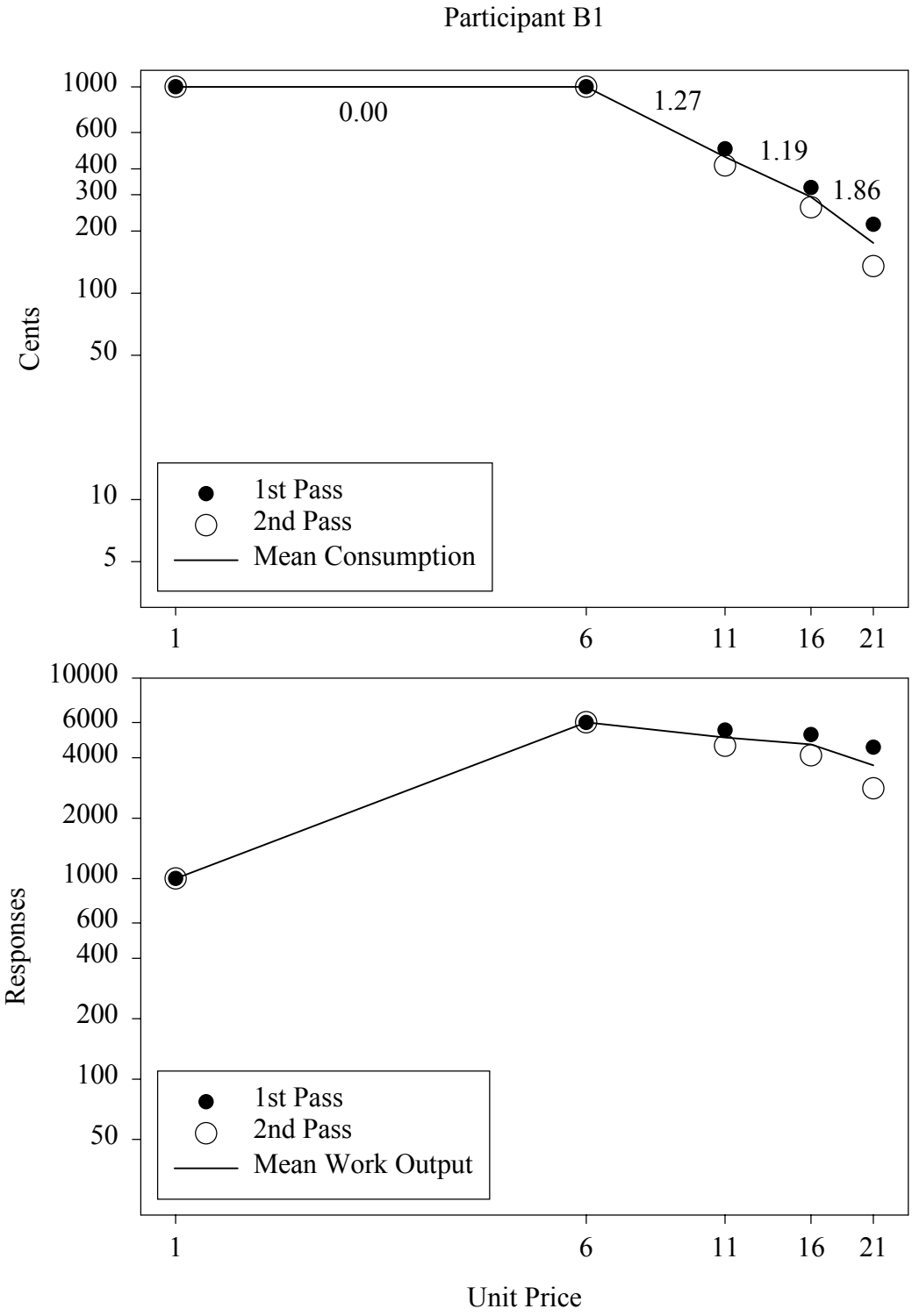


Figure 6. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

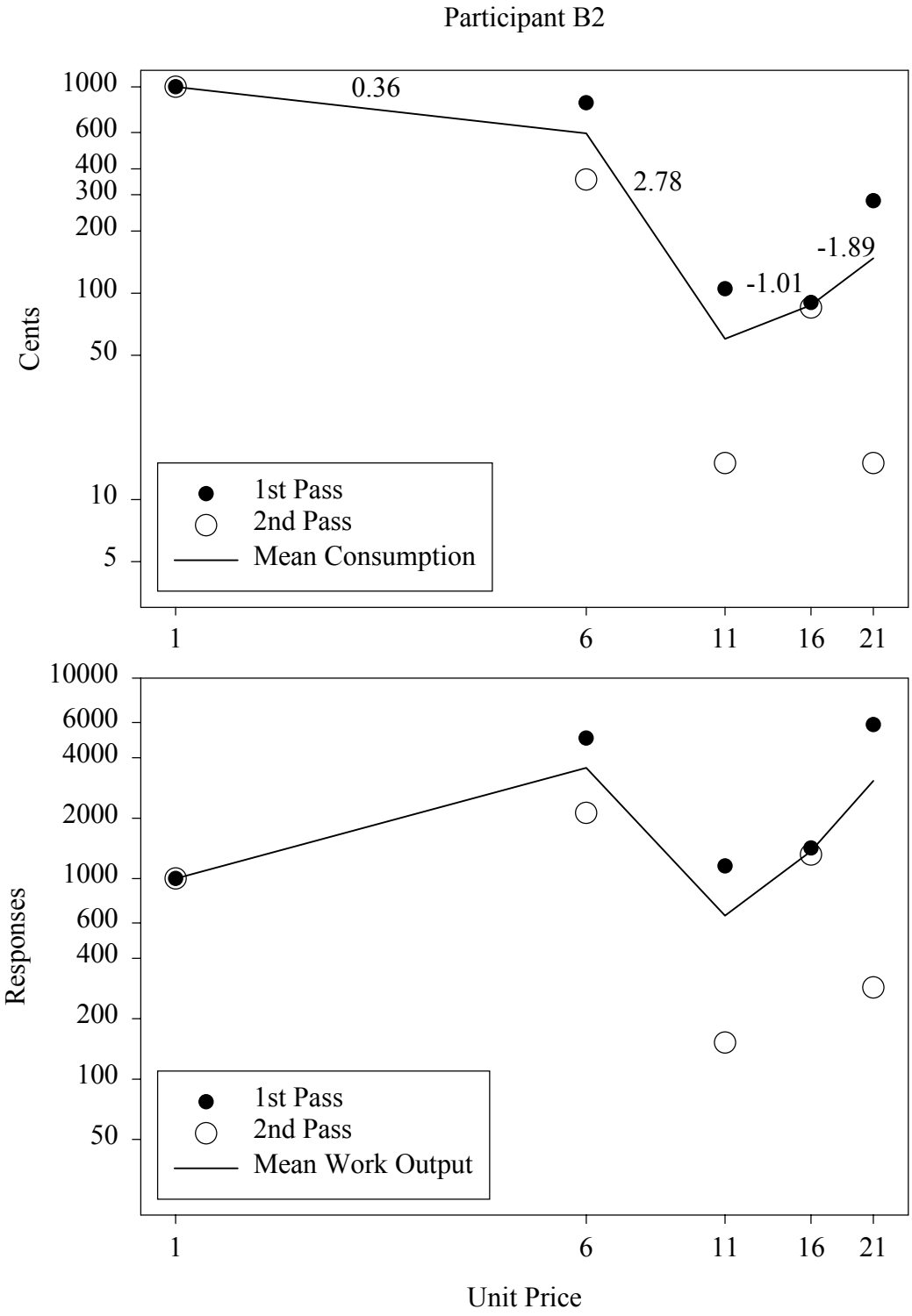


Figure 7. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

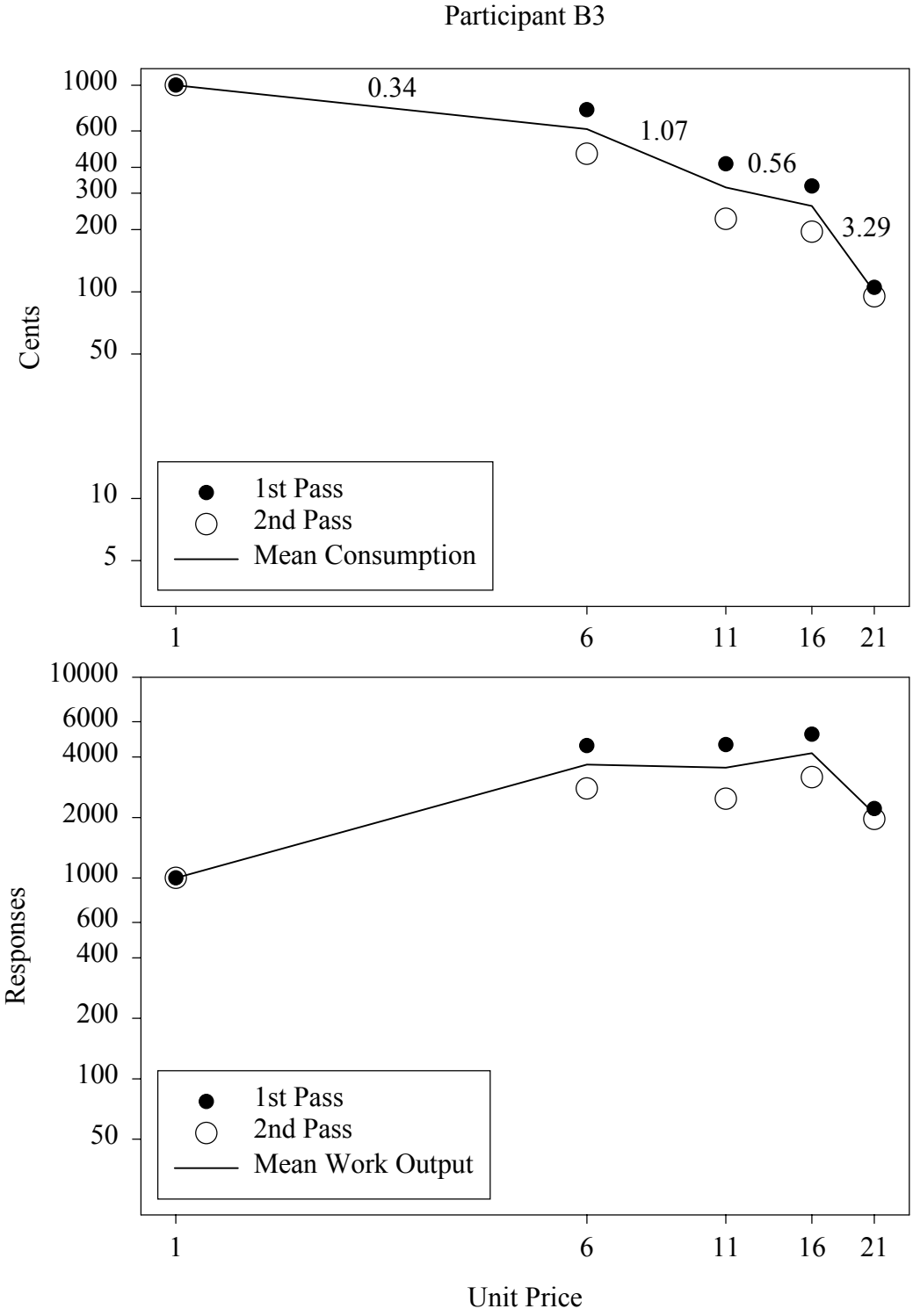


Figure 8. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

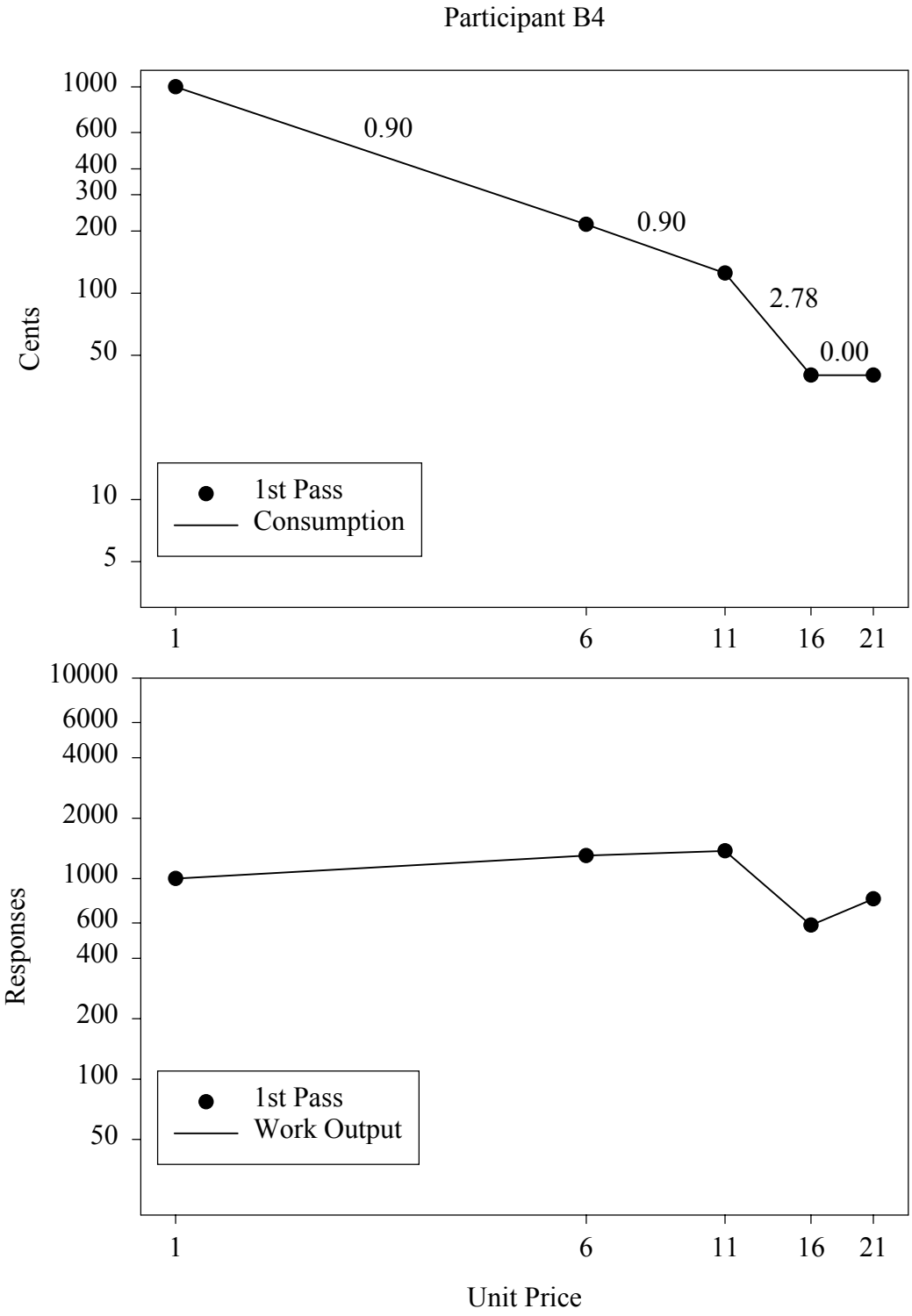


Figure 9. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

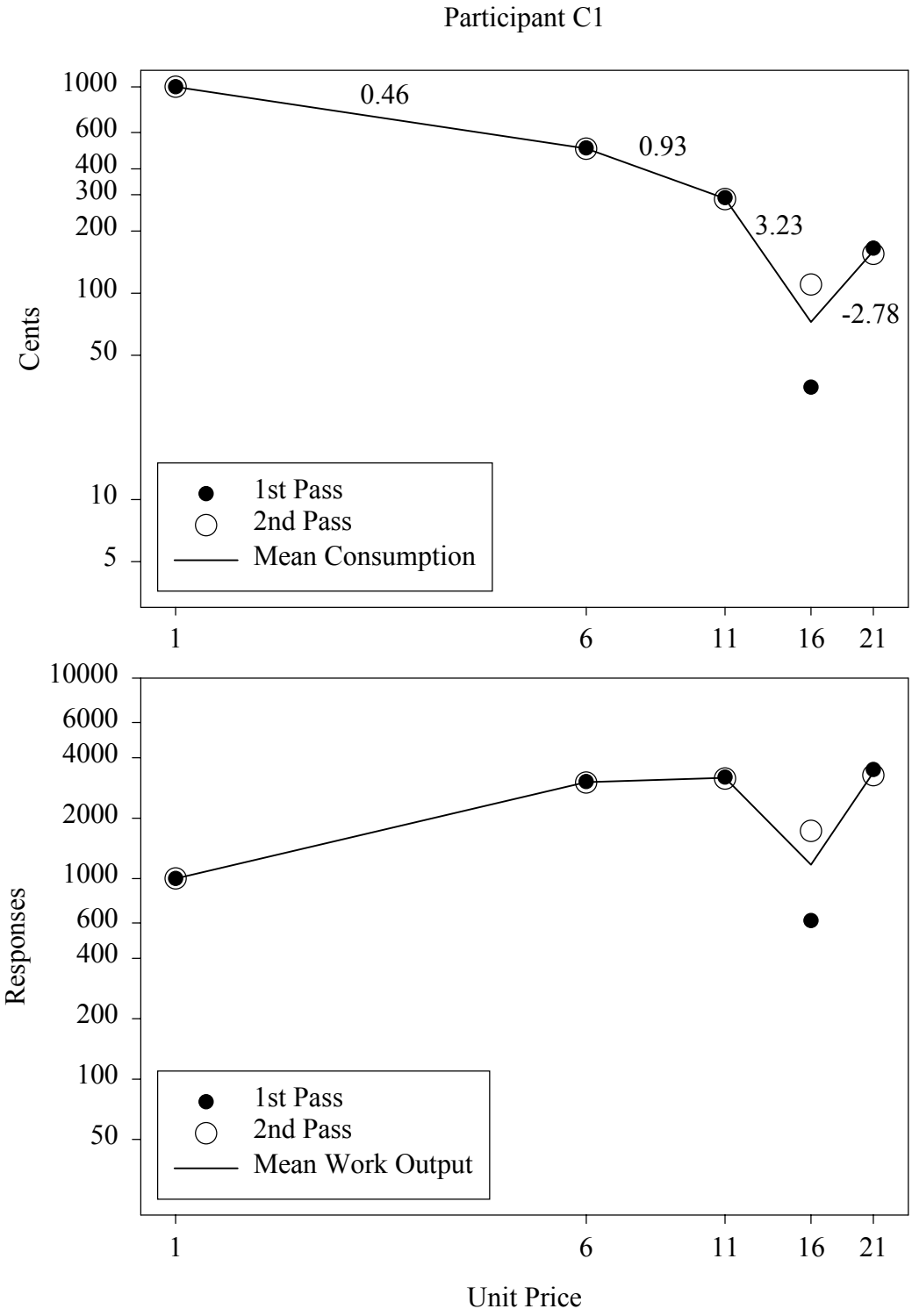


Figure 10. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

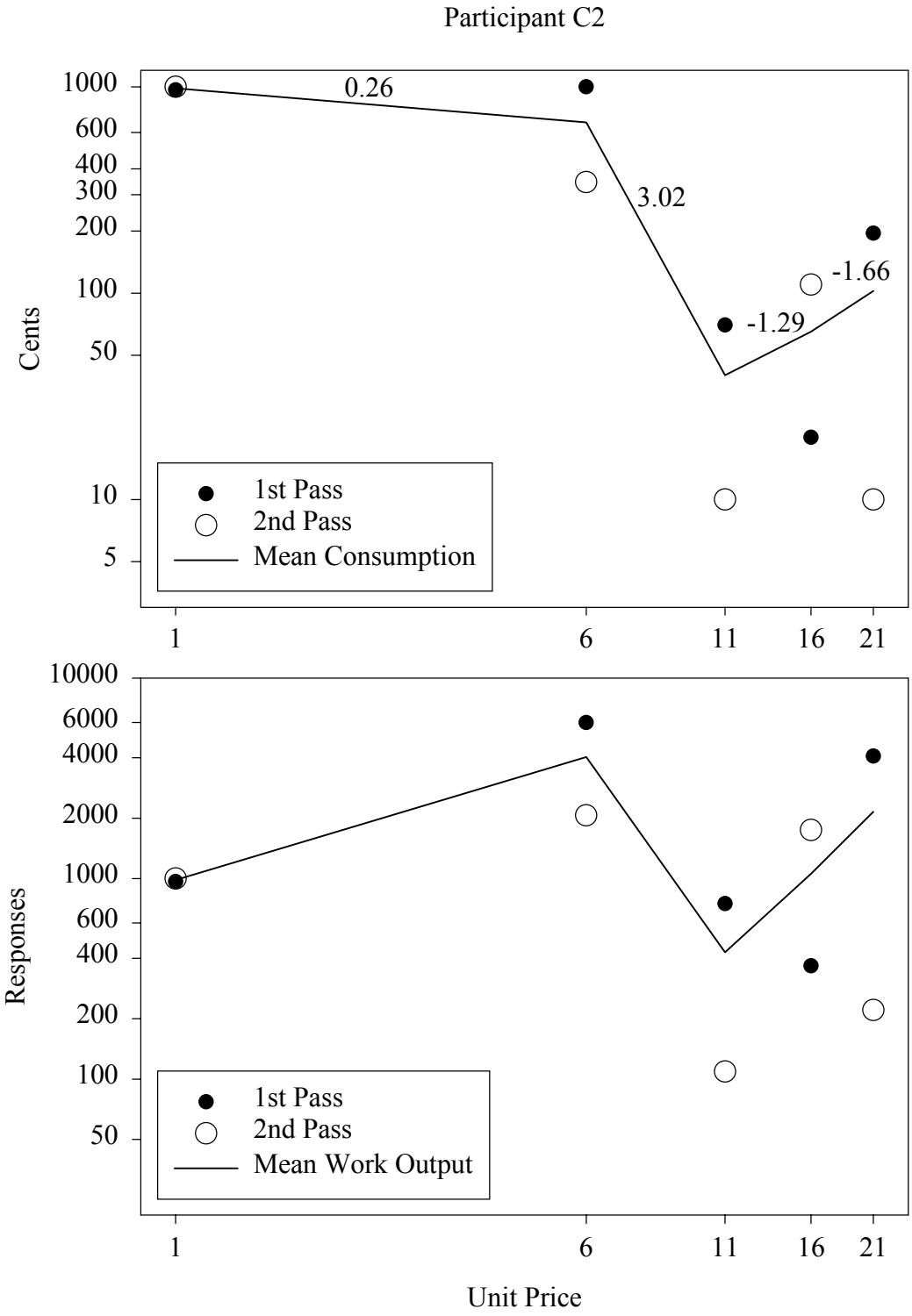


Figure 11. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

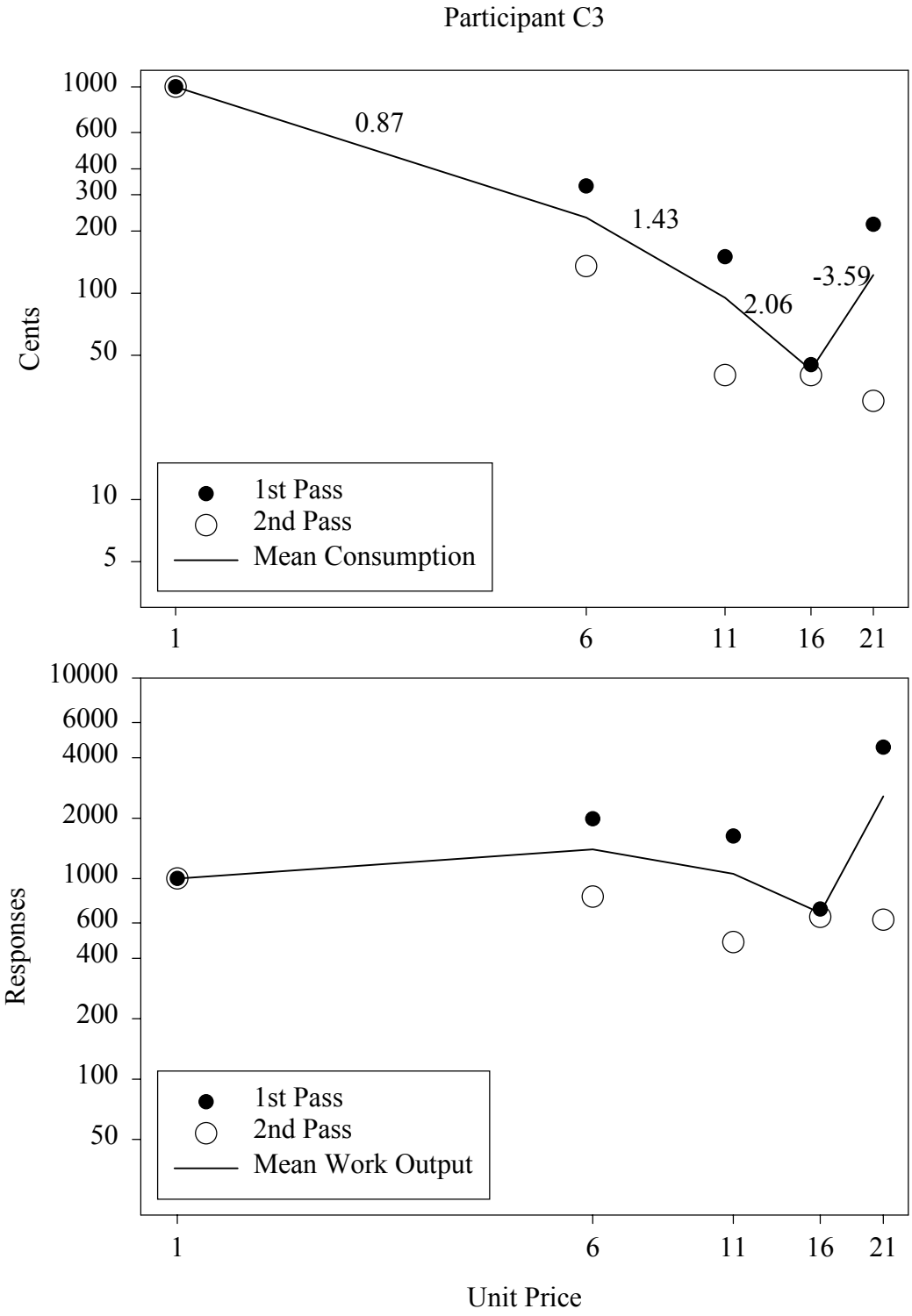


Figure 12. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

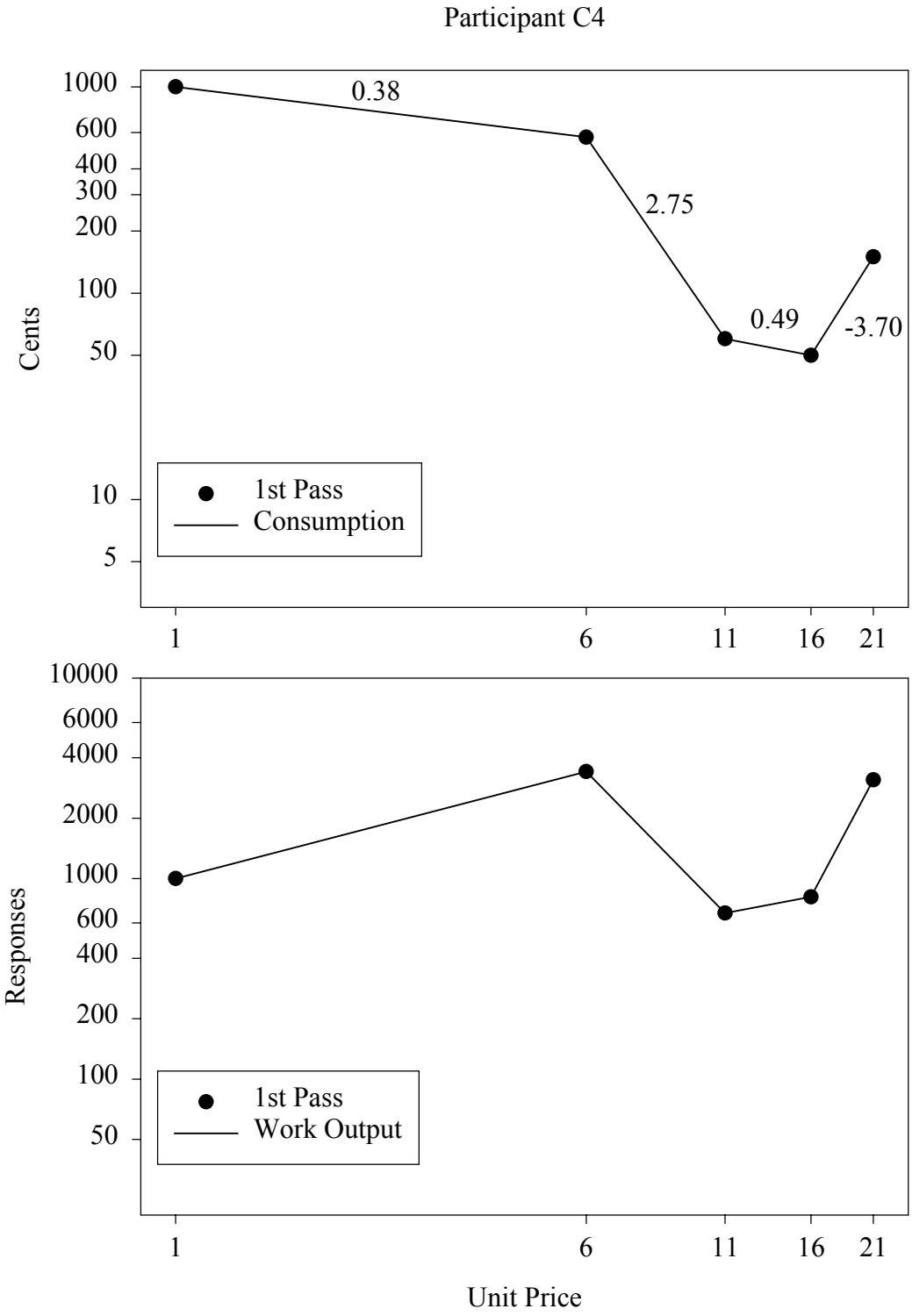
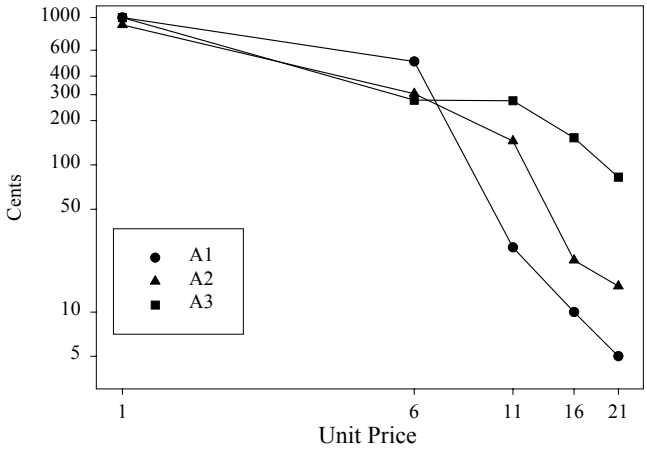


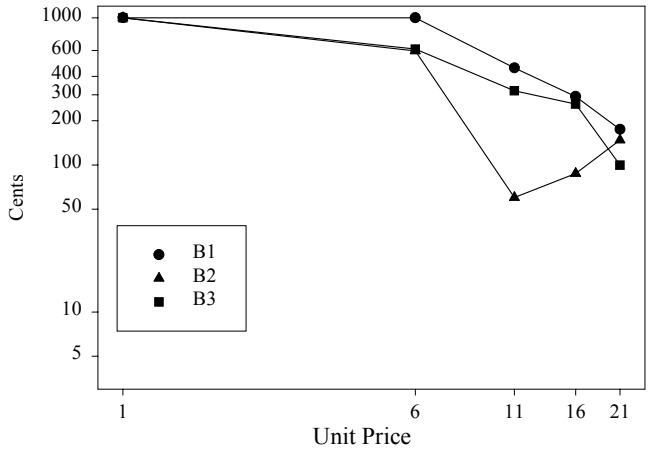
Figure 13. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

Demand Curves- Average Consumption
Group A (Top), Group B (Middle), Group C (Bottom)

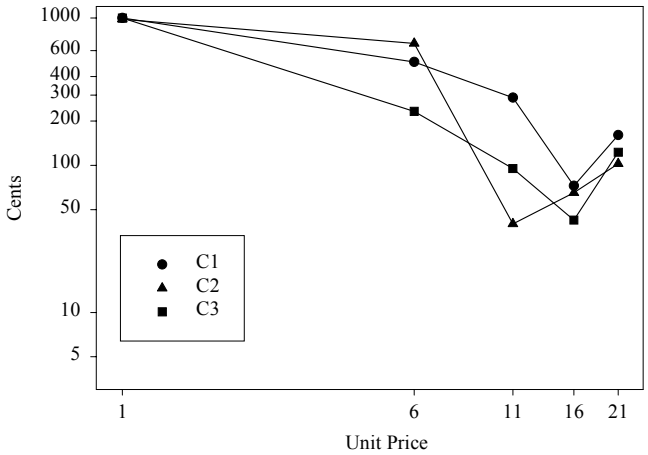


Sequence

1, 6, 11, 16, 21



1, 11, 6, 16, 21



1, 21, 6, 16, 11

Figure 14. Demand curve for all Groups plotted in log-log coordinates. Date points represent average consumption between both exposures.

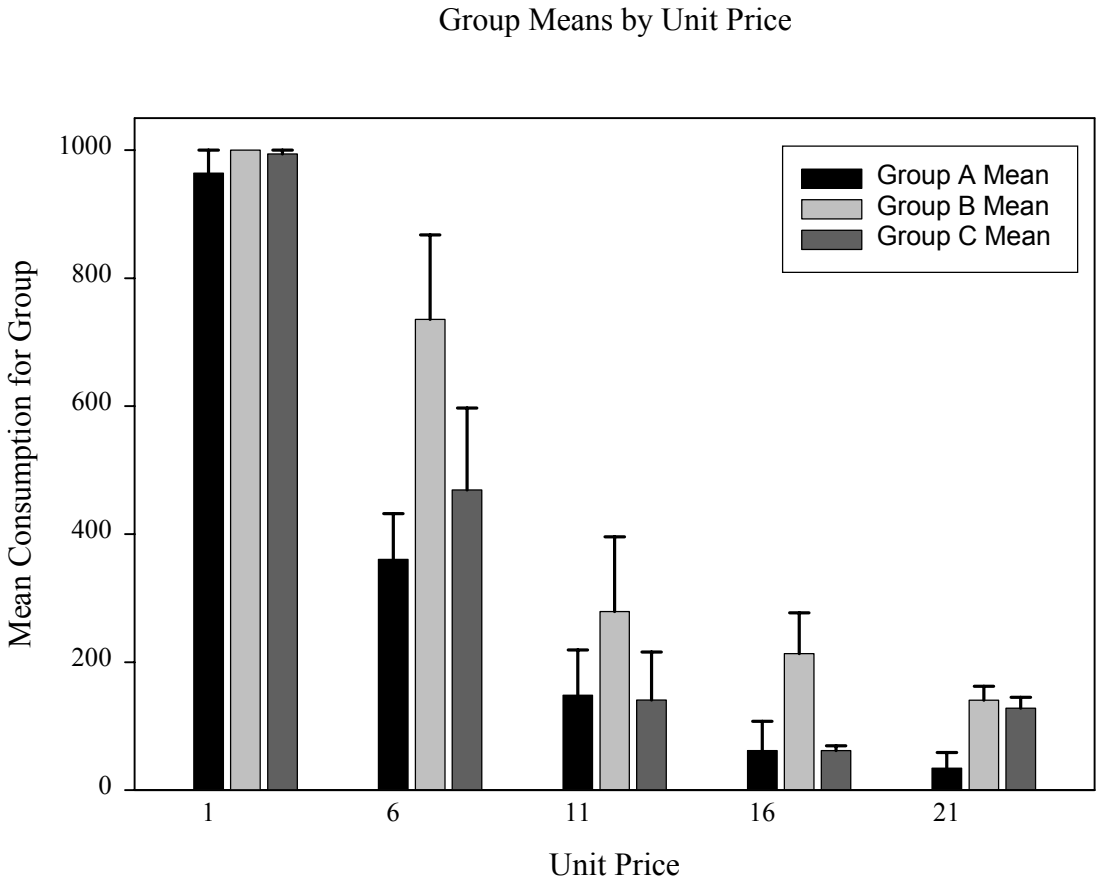


Figure 15. Group aggregate mean consumption for each unit price with standard error notations.

Session Duration

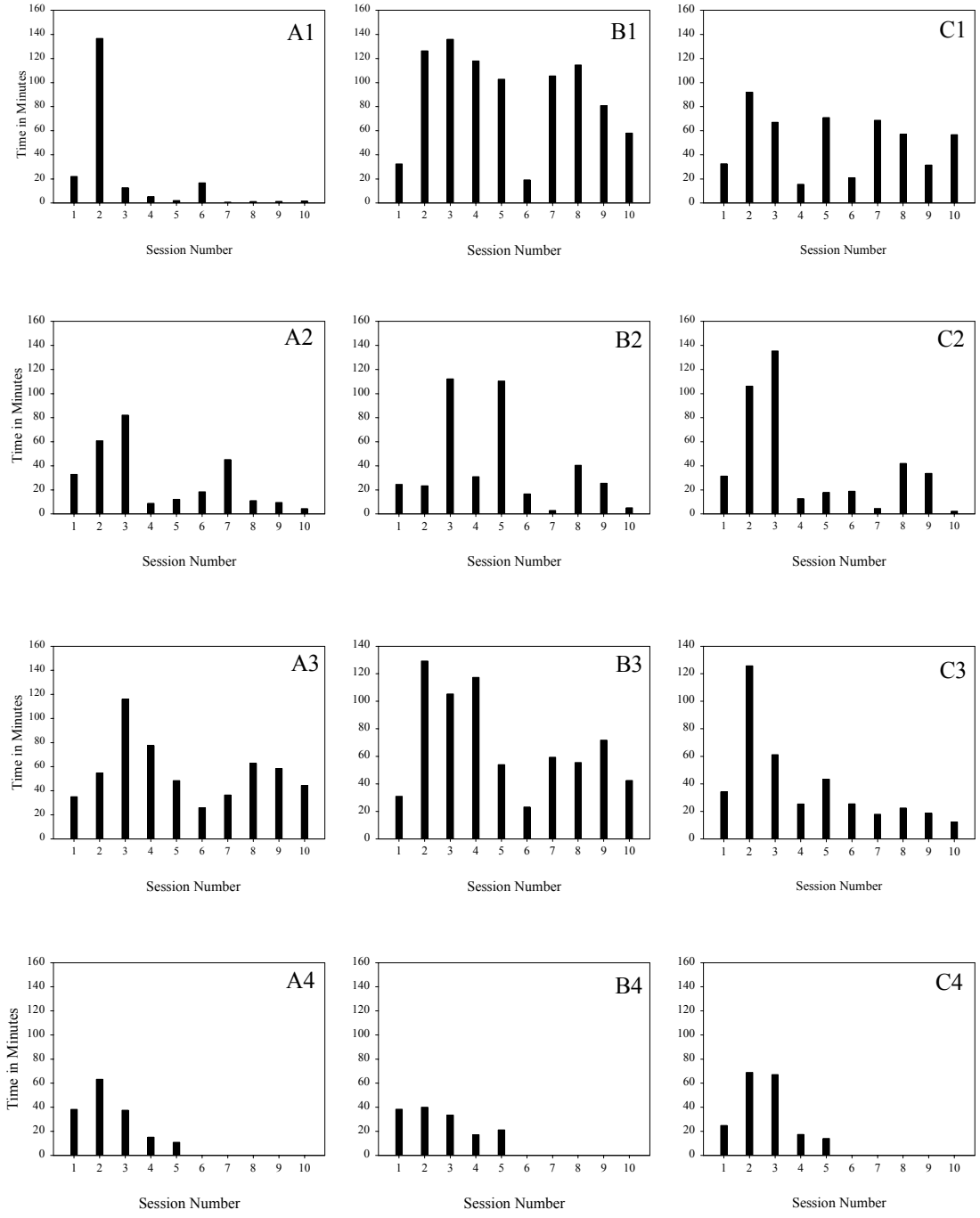


Figure 16. Session duration for each session in minutes.

REFERENCES

Allison, J. (1983). Behavioral Economics. New York: Praeger Publishers.

Bailey, K. (2001). The effect of consumption feedback on demand for money as a commodity. Unpublished master's thesis, University of North Texas, Denton, Texas.

Barlow, D. & Hersen, M. (1984). Single case experimental designs. New York: Pergamon Press.

Bickel, W. K., DeGrandpre, R. J., & Higgins, S. T. (1995). The behavioral economics of concurrent drug reinforcers: A review and reanalysis of drug self-administration research. Psychopharmacology, 118, 250-259.

Bickel, W. K., DeGrandpre, R. J., Higgins, S. T., & Hughes, J. R. (1990). Behavioral economics of drug self-administration. I. Functional equivalence of response requirement and drug dose. Life Sciences, 47, 15.1-1510.

Bickel, W. K., DeGrandpre, R. J., Hughes, J. R., & Higgins, S. T. (1991). Behavioral economics of drug self-administration II. A unit-price analysis of cigarette smoking. Journal of the Experimental Analysis of Behavior, 55, 145-154.

Bickel, W. K., Green, L. & Vuchinich, R. E. (1995). Behavioral economics. Journal of the Experimental Analysis of Behavior, 64, 257-262.

Bickel, W. K., Hughes, J. R., DeGrandpre, R. J., Higgins, S. T., & Rizzuto, P. (1992). Behavioral economics of drug self-administration IV. The effects of response requirement on the consumption of and interaction between concurrently available coffee and cigarettes. Psychopharmacology, 107, 211-216.

Carroll, M. E., Carmona, G. G., & May, S. A. (1991). Modifying drug reinforced behaviorl by altering the economic conditions of the drug and nondrug reinforcer. Journal of the Experimental Analysis of Behavior, 56, 361-376.

Case, D. A., Nichols, P., & Fantino, E. (1995). Pigeons' preference for variable-interval water reinforcement under widely varied water budgets. Journal of the Experimental Analysis of Behavior, 64, 299-311.

Catania, A.C. (1961). Behavioral contrast in a multiple and concurrent schedule of reinforcement. Journal of the Experimental Analysis of Behavior, 4, 335-342.

DeGrandpre, R. J., Bickel, W. K., Higgins, S. T., & Hughes, J. R. (1994). A behavioral economic analysis of concurrently available money and cigarettes. Journal of the Experimental Analysis of Behavior, 61, 191-201.

DeGrandpre, R. J., Bickel, W. K., Hughes, J. R., Layng, M. P., & Badger, G. (1993). Unit price as a useful metric in analyzing effects of reinforcer magnitude. Journal of the Experimental Analysis of Behavior, 60, 641-666.

Dougan, J. D., McSweeney, F. K., & Farmer-Dougan, V.A. (1986). Behavioral contrast in competitive and noncompetitive environments. Journal of the Experimental Analysis of Behavior, 46, 185-197.

Foltin, R. W. (1994). Does package size matter? A unit-price analysis of "demand" for food in baboons. Journal of the Experimental Analysis of Behavior, 62, 293-306.

Green, L. & Rachlin, H. (1991). Economic substitutability of electrical brain stimulation, food, and water. Journal of the Experimental Analysis of Behavior, 55, 133-143.

Hoffmeister, F. (1979). Progressive-ratio performance in rhesus monkey maintained by opiate infusions. Psychopharmacology, 62, 181-186.

Hursh, S. R. (1978). The economics of daily consumption controlling food and water-reinforced responding. Journal of the Experimental Analysis of Behavior, 29, 475-491.

Hursh, S. R. (1980). Economic concepts for the analysis of behavior. Journal of the Experimental Analysis of Behavior, 34, 219-238.

Hursh, S. R. (1984). Behavioral economics. Journal of the Experimental Analysis of Behavior, 42, 435-452.

Hursh, S. R. (1991). Behavioral economics of drug self-administration and drug abuse policy. Journal of the Experimental Analysis of Behavior, 56, 377-393.

Hursh, S. R. (1993). Behavioral economics of drug self-administration: An introduction. Drug and Alcohol Dependence, 33, 165-172.

Hursh, S. R. & Baumon, R. A. (1987). The behavioral analysis of demand. In L. Green & J. H. Kagel (Eds.), Advances in behavioral economic: Volume 1 (pp. 117-165). Norwood, NJ: Ablex Publishing Corporation.

Hursh, S. R., Raslear, T. G., Shurtleff, D., Bauman, R., & Simmons, L. (1988). A cost-benefit analysis of demand for food. Journal of the Experimental Analysis of Behavior, 50, 419-440.

Hursh, S. R., & Winger, G. (1995). Normalized demand for drugs and other reinforcers. Journal of the Experimental Analysis of Behavior, 64, 373-384.

Heyman, G. M., & Tanz, L. (1995). How to teach a pigeon to maximize overall reinforcement rate. Journal of the Experimental Analysis of Behavior, 64, 263-276.

Madden, G. J., Bickel, W. K., & Jacobs, E. A. (2000). Three predictions of the economic concept of unit price in a choice context. Journal of the Experimental Analysis of Behavior, 73, 45-64.

Myerson, J., & Green, L. (1995). Discounting of delayed rewards: Models of individual choice. Journal of the Experimental Analysis of Behavior, 64, 263-276.

Nevin, J. A. (1995). Behavioral economics and behavioral momentum. Journal of the Experimental Analysis of Behavior, 64, 385-395.

Reyes, J.R. (2000). A behavioral economic analysis of the demand for money in humans: The effects of unit price structure, price description and price sequence. Unpublished master's thesis, University of North Texas, Denton, Texas.

Reynolds, G.S. (1961). Behavioral contrast. Journal of the Experimental Analysis of Behavior, 4, 57-71.

Samuelson, P. A., & Nordhaus, W. D. (1985). Economics. New York, NY: McGraw Hill.

Viken, K. (1999). Elasticity of money as a reinforcer: Assessing multiple compositions of unit price. Unpublished master's thesis, University of North Texas, Denton, Texas.